UNIVERSITY OF DELHI

CNC-II/093/1(23)/2022-23/451
Dated: 03.03.2023

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

Sub: Amendment to Ordinance V

[E.C Resolution No. 38-1/ (38-1-4) dated 08.12.2022]

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-II of the following departments under Faculty of Mathematical Sciences based on Under Graduate Curriculum Framework -2022 to be implemented from the Academic Year 2022-23.

FACULTY OF MATHEMATICAL SCIENCES

DEPARTMENT OF MATHEMATICS

Category-I
B.Sc. (Hons.) Mathematics

DISCIPLINE SPECIFIC CORE COURSE – 4: 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		
Linear Algebra	4	3	1	0	Class XII pass with Mathematics	DSC-I: Algebra

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

- The concept of vectors in R^n, and their linear independence and dependence.
- Rank and nullity of linear transformations through matrices.
- Various applications of vectors in computer graphics and movements in plane.

Learning Outcomes: This course will enable the students to:

- Visualize the space R^n in terms of vectors and their interrelation with matrices.
- Familiarize with basic concepts in vector spaces, linear independence and span of vectors over a field.
- Learn about the concept of basis and dimension of a vector space.
- Basic concepts of linear transformations, dimension theorem, matrix representation of a linear transformation with application to computer graphics.

SYLLABUS OF DSC-4

UNIT – I: Matrices and System of Linear Equations (18 hours)

Fundamental operations with vectors in Euclidean space R^n, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving linear systems using Gaussian elimination, Gauss-Jordan row reduction, Reduced row echelon form, Equivalent systems, Rank and row space, Eigenvalues, Eigenvectors, Eigenspace, Diagonalization, Characteristic polynomial of a matrix, Cayley-Hamilton theorem.

UNIT – II: Introduction to Vector Spaces (12 hours)

Vector spaces, Subspaces, Algebra of subspaces, Linear combination of vectors, Linear span, Linear independence, Bases and dimension, Dimension of subspaces.

UNIT – III: Linear Transformations (15 hours)

Linear transformations, Null space, Range, Rank and nullity of a linear transformation, Matrix representation of a linear transformation, Algebra of linear transformations, Invertibility and isomorphisms; Application**:** Computer Graphics-Fundamental movements in a plane, homogenous coordinates, composition of movements.

Essential Readings

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.
2. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). *Linear Algebra* (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.

Suggestive Readings

- Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
- Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.
- Hoffman, Kenneth, & Kunze, Ray Alden (1978). *Linear Algebra* (2nd ed.). Prentice Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.

DISCIPLINE SPECIFIC CORE COURSE – 5: 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		
Calculus	**4**	**3**	**1**	**0**	**Class XII pass with Mathematics**	**DSC-2: Elementary Real Analysis**

Learning Objectives: The primary objective of this course is:

- To introduce the basic tools of calculus, also known as 'science of variation'.
- To provide a way of viewing and analyzing the real-world.

Learning Outcomes: This course will enable the students to understand:

- The notion of limits, continuity and uniform continuity of functions.
- Geometrical properties of continuous functions on closed and bounded intervals.
- Applications of derivative, relative extrema and mean value theorems.
- Higher order derivatives, Taylor's theorem, indeterminate forms and tracing of curves.

SYLLABUS OF DSC-5

UNIT – I: Limits and Continuity **(15 hours)**

Limits of functions (ε - δ and sequential approach), Algebra of limits, Squeeze theorem, One-sided limits, Infinite limits and limits at infinity; Continuous functions and its properties on closed and bounded intervals; Uniform continuity.

UNIT – II: Differentiability and Mean Value Theorems **(15 hours)**

Differentiability of a real-valued function, Algebra of differentiable functions, Chain rule, Relative extrema, Interior extremum theorem, Rolle's theorem, Mean-value theorem and its applications, Intermediate value theorem for derivatives.

UNIT – III: **(15 hours)**

Successive Differentiation, Taylor's Theorem and Tracing of Plane Curves

Higher order derivatives and calculation of the nth derivative, Leibnitz's theorem; Taylor's theorem, Taylor's series expansions of e^x, $\sin x$, $\cos x$. Indeterminate forms, L'Hôpital's rule; Concavity and inflexion points; Singular points, Asymptotes, Tracing graphs of rational functions and polar equations.

Essential Readings

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pvt. Ltd. Reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Bartle, Robert G., & Sherbert, Donald R. (2011). *Introduction to Real Analysis* (4th ed.). John Wiley & Sons. Wiley India edition reprint.

3. Prasad, Gorakh (2016). *Differential Calculus* (19th ed.). Pothishala Pvt. Ltd. Allahabad.
4. Ross, Kenneth A. (2013). *Elementary Analysis*: *The Theory of Calculus* (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian reprint.

Suggestive Readings

- Apostol, T. M. (2007). *Calculus*: *One-Variable Calculus with an Introduction to Linear Algebra* (2nd ed.). Vol. 1. Wiley India Pvt. Ltd.
- Ghorpade, Sudhir R. & Limaye, B. V. (2006). *A Course in Calculus and Real Analysis*. Undergraduate Texts in Mathematics, Springer (SIE). Indian reprint.

DISCIPLINE SPECIFIC CORE COURSE – 6: ORDINARY 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		
Ordinary Differential Equations	4	3	0	1	Class XII pass with Mathematics	NIL

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

- The exciting world of differential equations.
- Their applications and mathematical modeling.

Learning Outcomes: The course will enable the students to:

- Learn the basics of differential equations and compartmental models.
- Formulate differential equations for various mathematical models.
- Solve first order non-linear differential equations, linear differential equations of higher order and system of linear differential equations using various techniques.
- Apply these techniques to solve and analyze various mathematical models.

SYLLABUS OF DSC-6

UNIT – I: First-Order Differential Equations (12 hours)

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

UNIT – II: Second and Higher-Order Differential Equations (18 hours)

General solution of homogenous equation of second order, Principle of superposition for a homogenous equation, Wronskian and its properties, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Method of variation of parameters, Method of undetermined coefficients, Two-point boundary value problems, Cauchy- Euler's equation, System of linear differential equations, Application of second order differential equation: Simple pendulum problem.

UNIT – III: Formulation and Analysis of Mathematical Models (15 hours)

Introduction to compartmental models, Lake pollution model; Density-dependent growth model, Interacting population models, Epidemic model of influenza and its analysis, Predator-prey model and its analysis, Equilibrium points, Interpretation of phase plane

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

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

1. Solutions of first, second and third order differential equations.
2. Plotting of family of solutions of differential equations of first, second and third order.
3. Solution of differential equations using method of variation of parameters.
4. Growth and decay model (exponential case only).
5. Lake pollution model (with constant/seasonal flow and pollution concentration).
6. Density-dependent growth model.
7. Predatory-prey model (basic Volterra model, with density dependence, effect of DDT, two prey one predator).
8. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).

Essential Readings

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

Suggestive Reading

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

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

BA. (Prog.) with Mathematics as Major

Category II

DISCIPLINE SPECIFIC CORE COURSE (DSC-2): ANALYTIC GEOMETRY

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		
Analytic Geometry	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The course aims at:

- Identifying and sketching curves, studying three dimensional objects, their geometric properties and applications.
- Use of vector approach to three-dimensional geometry makes the study simple and elegant.

Learning Outcomes: This course will enable the students to:

- Learn concepts in two-dimensional geometry.
- Identify and sketch conics namely, ellipse, parabola and hyperbola.
- Learn about three-dimensional objects such as straight lines and planes using vectors, spheres, cones and cylinders.

SYLLABUS OF DSC-2

UNIT – I: Conic Sections **(15 hours)**

Techniques for sketching parabola, ellipse and hyperbola; Reflection properties of parabola, ellipse, hyperbola, and their applications to signals; Classification of quadratic equation representing lines, parabola, ellipse and hyperbola; Rotation of axes; Second degree equations.

UNIT – II: Vectors, Lines and Planes **(18 hours)**

Rectangular coordinates in 3-dimensional space, vectors viewed geometrically, vectors in coordinate systems and vectors determined by length and angle; Dot product; Projections; Cross product, scalar triple product, vector triple product and their geometrical properties; Parametric equations of lines, direction cosines and direction ratios of a line, vector and symmetric equations of lines, angle between two lines; Planes in 3-dimensional space, coplanarity of two lines, angle between two planes, distance of a point from a plane, angle between a line and a plane, distance between parallel planes; Shortest distance between two skew lines.

UNIT – III: Sphere, Cone and Cylinder **(12 hours)**

Equation of a sphere, plane section of sphere, tangents and tangent plane to a sphere; Equation of a cone, enveloping cone of a sphere, Reciprocal cones and right circular cone; Equation of a cylinder, enveloping cylinder and right circular cylinder.

Essential Readings

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Indian reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Narayan, Shanti & Mittal, P. K. (2007). *Analytical Solid Geometry*. S. Chand & Company Pvt Ltd. India.

Suggestive Readings

- Bell, Robert J.T. (1972). *An Elementary Treatise on Coordinate Geometry of Three Dimensions*. Macmillan & Co. Ltd. London.
- George B. Thomas, Jr., & Ross L. Finney (2012). *Calculus and Analytic Geometry* (9th ed.). Pearson Indian Education Services Pvt Ltd. India.

DISCIPLINE SPECIFIC CORE COURSE – 2 (Discipline A-2): Elementary 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		
Elementary Linear Algebra	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The objective of the course is:

- To introduce the concept of vectors in R^n.
- Understanding the nature of solution of system of linear equations.
- To view the $m \times n$ matrices as a linear function from R^n to R^m and vice versa.
- To introduce the concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

Learning Outcomes: This course will enable the students to:

- Visualize the space R^n in terms of vectors and the interrelation of vectors with matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vector spaces.
- Learn about linear transformation and its corresponding matrix.

SYLLABUS OF DSC-2

UNIT – I: Euclidean Space R^n and Matrices **(18 hours)**

Fundamental operations with vectors in Euclidean space R^n, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving system of linear equations using Gaussian elimination, Application: Curve Fitting, Gauss-Jordan row reduction, Reduced row echelon form, Application: Solving several systems simultaneously, Equivalent systems, Rank and row space of a matrix, Eigenvalues, Eigenvectors, Eigenspace, Diagonalization, Characteristic polynomial of a matrix.

UNIT – II: Introduction to Vector Spaces **(12 hours)**

Definition, Examples and some elementary properties of vector spaces, Subspaces, Span, Linear independence and linear dependence of vectors, Basis and dimension of a vector space, Maximal linearly independent sets, Minimal spanning sets.

UNIT – II: Linear Transformations **(15 hours)**

Linear transformations**:** Definition, Examples and elementary properties, The matrix of a linear transformation, Kernel and range of a linear transformation, The dimension theorem, one-to-one and onto linear transformations, Invertible linear transformations, Isomorphic vector spaces.

Essential Reading

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.

Suggestive Readings

- Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
- Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.

B.Sc. (Prog.)/ BA (Prog.) with Mathematics as Non-Major

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 2 (Discipline A-2): Elementary 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		
Elementary Linear Algebra	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The objective of the course is:

- To introduce the concept of vectors in R^n.
- Understand the nature of solution of system of linear equations.
- To view the $m \times n$ matrices as a linear function from R^n to R^m and vice versa.
- To introduce the concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

Learning Outcomes: This course will enable the students to:

- Visualize the space R^n in terms of vectors and the interrelation of vectors with matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vector spaces.
- Learn about linear transformation and its corresponding matrix.

SYLLABUS OF DSC-2

UNIT – I: Euclidean Space R^n and Matrices **(18 hours)**

Fundamental operations with vectors in Euclidean space R^n, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz inequality, Triangle inequality, Solving system of linear equations using Gaussian elimination, Application: Curve Fitting, Gauss-Jordan row reduction, Reduced row echelon form, Application: Solving several systems simultaneously, Equivalent systems, Rank and row space of a matrix, Eigenvalues, Eigenvectors, Eigenspace, Diagonalization, Characteristic polynomial of a matrix.

UNIT – II: Introduction to Vector Spaces **(12 hours)**

Definition, Examples and some elementary properties of vector spaces, Subspaces, Span, Linear independence and linear dependence of vectors, Basis and dimension of a vector space, Maximal linearly independent sets, Minimal spanning sets.

UNIT – III: Linear Transformations **(15 hours)**

Linear transformations**:** Definition, Examples and elementary properties, The matrix of a linear transformation, Kernel and range of a linear transformation, The dimension theorem, one-to-one and onto linear transformations, Invertible linear transformations, Isomorphic vector spaces.

Essential Reading

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.

Suggestive Readings

- Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). *Linear Algebra and its Applications* (5th ed.). Pearson Education.
- Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.

(Category-IV)

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT OF MATHEMATICS

GENERIC ELECTIVES (GE-2(i)): ANALYTIC GEOMETRY

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		
Analytic Geometry	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The course aims at:

- Identifying and sketching curves, studying three dimensional objects, their geometric properties and applications.
- Use of vector approach to three-dimensional geometry makes the study simple and elegant.

Learning Outcomes: This course will enable the students to:

- Learn concepts in two-dimensional geometry.
- Identify and sketch conics namely, ellipse, parabola and hyperbola.
- Learn about three-dimensional objects such as straight lines and planes using vectors, spheres, cones and cylinders.

SYLLABUS OF GE-2(i)

UNIT – I: Conic Sections **(15 hours)**

Techniques for sketching parabola, ellipse and hyperbola; Reflection properties of parabola, ellipse, hyperbola, and their applications to signals; Classification of quadratic equation representing lines, parabola, ellipse and hyperbola; Rotation of axes; Second degree equations.

UNIT – II: Vectors, Lines and Planes **(18 hours)**

Rectangular coordinates in 3-dimensional space, vectors viewed geometrically, vectors in coordinate systems and vectors determined by length and angle; Dot product; Projections; Cross product, scalar triple product, vector triple product and their geometrical properties; Parametric equations of lines, direction cosines and direction ratios of a line, vector and symmetric equations of lines, angle between two lines; Planes in 3-dimensional space, coplanarity of two lines, angle between two planes, distance of a point from a plane, angle between a line and a plane, distance between parallel planes; Shortest distance between two skew lines.

UNIT – III: Sphere, Cone and Cylinder **(12 hours)**

Equation of a sphere, plane section of sphere, tangents and tangent plane to a sphere; Equation of a cone, enveloping cone of a sphere, Reciprocal cones and right circular cone; Equation of a cylinder, enveloping cylinder and right circular cylinder.

Recommended Readings:

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). *Calculus* (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Indian reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Narayan, Shanti & Mittal, P. K. (2007). *Analytical Solid Geometry*. S. Chand & Company Pvt Ltd. India.

Suggestive Readings:

- Bell, Robert J.T. (1972). *An Elementary Treatise on Coordinate Geometry of Three Dimensions*. Macmillan & Co. Ltd. London.
- George B. Thomas, Jr., & Ross L. Finney (2012). *Calculus and Analytic Geometry* (9th ed.). Pearson Indian Education Services Pvt Ltd. India.

GENERIC ELECTIVES (GE-2(ii)): INTRODUCTION TO 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
		Lecture	Tutorial	Practical/ Practice		
Introduction to Linear Algebra	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The objective of the course is:

- To introduce the concept of vectors in R^n.
- Understand the nature of solution of system of linear equations.
- To view the $m \times n$ matrices as a linear function from R^n to R^m and vice versa.
- To introduce the concepts of linear independence and dependence, rank and linear transformations has been explained through matrices.

Learning Outcomes: This course will enable the students to:

- Visualize the space R^n in terms of vectors and the interrelation of vectors with matrices.
- Understand important uses of eigenvalues and eigenvectors in the diagonalization of matrices.
- Familiarize with concepts of bases, dimension and minimal spanning sets in vector spaces.
- Learn about linear transformation and its corresponding matrix.

SYLLABUS OF GE-2(ii)

UNIT – I: Vectors and Matrices **(18 hours)**

Fundamental operations and properties of vectors in R^n, Linear combinations of vectors, Dot product and their properties, Cauchy-Schwarz and triangle inequality, Orthogonal and parallel vectors; Solving system of linear equations using Gaussian elimination, and Gauss-Jordan row reduction, Reduced row echelon form; Equivalent systems, Rank and row space of a matrix; Eigenvalues, eigenvectors and characteristic polynomial of a square matrix; Diagonalization.

UNIT – II: Vector Spaces **(12 hours)**

Definition, examples and some elementary properties of vector spaces; Subspaces, Span, Linear independence and dependence; Basis and dimension of a vector space; Diagonalization and bases.

UNIT – III: Linear Transformations **(15 hours)**

Definition, examples and elementary properties of linear transformations; The matrix of a linear transformation; Kernel and range of a linear transformation, The dimension theorem, one-to-one and onto linear transformations.

Essential Reading

1. Andrilli, S., & Hecker, D. (2016). *Elementary Linear Algebr*a (5th ed.). Elsevier India.

Suggestive Reading

- Kolman, Bernard, & Hill, David R. (2001). *Introductory Linear Algebra with Applications* (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.

DEPARTMENT OF OPERATIONAL RESEARCH

Category I

BSc. (Hons.) Operational Research

DISCIPLINE SPECIFIC CORE COURSE – 4: Advanced 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		
Advanced Linear Programming DSC-4	4	3	0	1	Class XII pass with Mathematics	Basic Linear Programming

Learning Objectives

The Learning Objectives of this course are as follows:

- To enrich the knowledge of students with advanced concepts and techniques of linear programming problem along with real life applications
- To make students understand the theoretical basics of different computational algorithms used in solving linear programming and related problems.

Learning outcomes

Students completing this course will be able to:

- Explain the relationship between a linear program and its dual, including strong duality and complementary slackness, and understand the economic interpretation of duality.
- Learn an alternative method for solving linear programming problems.
- Perform sensitivity analysis to identify the direction and magnitude of change of a linear programming model's optimal solution as the input data changes.
- Formulate specialized linear programming problems, namely transportation and assignment problems and describe theoretical workings of the solution methods for transportation and assignment problems, demonstrate solution process by hand and solver.

SYLLABUS OF DSC-4

Unit I (12 Hours): Duality: Duality in linear programming, Duality theorems (Weak duality, Strong duality, Existence theorem and Complementary slackness conditions), Economic interpretation of duality, Dual simplex method.

Unit II (09 Hours): Sensitivity Analysis: Post Optimality Analysis (change in resource vector, change in cost vector, addition and deletion of a constraint, addition and deletion of a decision variable).

Unit III (15 Hours): Transportation problem (TP) : TP and its formulation, finding initial basic feasible solution of TP using North-West Corner rule, Least Cost method and Vogel's Approximation method, MODI method for finding optimal solution, Special cases in TP.

Unit IV (09 Hours): Assignment problem (AP) : AP and its formulation, Hungarian method for solving AP, Special cases in AP, Transhipment and Travelling salesmen problem.

Practical component (if any) – 30 Hours

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Solution to linear programming problem through dual simplex method.
2. Computational sensitivity analysis with respect to changes in the cost vector.
3. Computational sensitivity analysis with respect to changes in the resource vector.
4. Solution of transportation problem.
5. Solution of assignment problem.
6. Solution of travelling salesman problem.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J. and Sherali. H. D. (2011). *Linear Programming and Network Flows* (4th ed.). John Wiley & Sons.
- Chandra, S., Jayadeva, Mehra, A. (2009). *Numerical Optimization with Applications*. Narosa Publishing House.
- Hadley, G. (2002). *Linear Programming.* Narosa Publishing House.
- Ravindran, A., Phillips, D. T. and Solberg, J. J. (2007). *Operations Research-Principles and Practice* (2nd ed.) (WSE), John Wiley & Sons.
- Taha, H. A. (2017). *Operations Research-An Introduction* (10th ed.). Pearson.
- Winston, W. L. and Venkataramanan, M. (2002). *Introduction to Mathematical Programming: 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 – 5: 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		
Statistics DSC-5	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- The aim of this course is to acquaint the students with the fundamental concepts of Probability and Statistics, to provide an understanding of the processes by which real-life statistical problems are analysed
- To develop an understanding of the role of Statistics in Operational Research.

Learning Outcomes

Students completing this course will be able to:

- Quantify uncertainty using probability, learn how to find probability using the concepts of random variables and distribution functions, obtain characteristics of the underlying distributions, and study functional relationships between two random variables.
- Know various discrete and continuous probability distributions along with their characteristics and identify the situations where they provide realistic models.
- Know about the modes of convergence in probability theory.
- Define the functional relationship between two variables and gain a foothold in basic concepts of forecasting.

SYLLABUS OF DSC-5

Unit I (06 Hours): Probability: Probability Axioms, Conditional Probability and Bayes' Theorem and its Applications.

Unit II (15 Hours): Random Variables, Distribution Functions and Moments: Introduction, Expectation and Variance, Moment Generating Functions and Characteristic Function, Multidimensional Random Variable, Conditional Expectation and Conditional Variance. Joint, Marginal and Conditional Distributions. Independent Random Variables.

Unit III (15 Hours): Probability Distributions and Large Sample Theory: Discrete and Continuous Probability Distributions (Binomial, Poisson, Geometric Negative binomial, Uniform, Exponential, Normal), Weak Law of Large Numbers, Strong Law of Large Numbers. Central Limit Theorem.

Unit IV (9 Hours): Regression and Forecasting: Karl Pearson's Coefficient of Correlation, Lines of regression, Introduction to Forecasting.

Practical component (if any) -

1. Practicals to Analyse frequency distribution using moments.
2. Practicals to demonstrate applications of Binomial, Poisson and Normal Distributions
3. Practicals to understand Fitting of discrete distributions-Binomial, Poisson, Negative Binomial
4. Fitting of continuous distributions-Exponential. Normal
5. Finding Karl Pearson's Correlation Coefficient using raw and grouped data
6. Analysis of data to be used for forecasting- graphically, using summary statistics, and various measures of forecasting accuracy that are used to help judge the appropriateness of a model
7. Regression Analysis and forecasting using Lines of regression

Essential/recommended readings

- Makridakis, S., Wheelwright, S. C., & Hyndman, R. J. (2008). *Forecasting methods and applications*. John wiley & sons.
- Devore, J. L. (2012). *Probability and Statistics for Engineering and the Sciences* (8th ed.) Cengage Learning.
- Gupta, S.C, Kapoor, V K (2020). *Fundamentals of Mathematical Statistics* (12th Ed.) Sultan Chand and Sons.
- Rohatgi, V. K., & Saleh, A. K. E. Md. (2015). *An Introduction to Probability and Statistics* (3nd ed.). Wiley.
- Ross, S. (2014). *Introduction to Probability Models* (11th ed.). Academic Press/Elsevier.

Suggestive readings

- Feller, W. (2008). *An Introduction to Probability Theory and its Applications - Vol I* (3rd ed.). Wiley.
- Hogg, R.V., Craig, A.T., and Mckean, J.W. (2019). *Introduction to Mathematical Statistics* (8th ed.). Pearson.

DISCIPLINE SPECIFIC CORE COURSE – 6: Python Programming for Business 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		
Python Programming for Business Modelling DSC-6	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**Nil**

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce the basic concepts of Python programming. The course will familiarize the students with Python's ability to handle different data formats such as numbers, strings, lists, dictionaries, sets, tuples, etc.
- The students will be made familiar with the concepts of loops. Modularization of code using inbuilt functions as well as user defined functions will also be explained.
- To introduce the basics for various useful libraries so as to equip the students with modern computing skills.

Learning outcomes

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

- Learn Python installation and configuration.
- Understand simple scripting using Python.
- Learn Syntax and Semantics of Python Programming.
- Understand different data types and arithmetical, logical and relational expressions in Python.
- Understand the control structures and functions in Python by writing codes for some real-world problems.
- Handle simple data structures, lists, dictionaries, sets and tuples.
- Modularize the code using inbuilt functions and user defined functions.
- Handle various managerial decision making related problems

SYLLABUS OF DSC-6

Unit I (6 Hours)
Python installation, Basic Terminal Commands, interactive mode and script mode, Structure of a Program, Simple Python Script Writing, script execution, debugging errors and understanding simple programs in Python

Unit II (12 Hours)
Identifiers and keywords; literals, numbers, and strings; Operators and expressions; Input and Output statements; control structures (conditional statements, loop control statements, break, Continue and pass).

Unit III (10 Hours)
Introduction to Functions and its definition: Modules, built in and user-defined functions, passing arguments and returning values, default arguments, functions as data.

Unit IV (8 Hours)
Data Structures: Strings, Lists, Tuples, Sets, Dictionaries, Analysing their functions and basic operations.

Unit V (9 Hours): Introduction to Core Libraries in Python : Numpy Library for Arrays (Creating and accessing One and Multi-Dimensional Array), Pandas Library for Data Processing (Basics of DataFrame), Matplotlib Library for Visualization (Pie Chart, Scatter Plot, Histogram, Bar Chart), SciPy Library for Statistics (for handling basic statistics like; Descriptive Statistics, Rank, Determining Homogeneity of Variances, Correlation), Using PuLP for solving Linear Programming Problems

Practical component (if any) –

1. Write a program to enter a name and display: "Hello, Name".
2. Write a program to compute the roots of a quadratic equation.
3. Write a program to print a pyramid **pattern** with 8 rows.
4. Write a menu-driven program to enter a number and print whether the number is odd or even.
5. Write a program to build a **random number generator** that generates random numbers between 1 and 6 (simulates a dice).
6. Write a program that takes two **lists** and returns "True" if they have at least one common member.
7. Write a program to check if one **list** is reverse of another.
8. Write a program to check if a given **array** is Monotonic.
9. Write a program to find the maximum number out of 3 entered numbers. **(loop)**
10. Write a program to build a menu driven **calculator** and perform basic arithmetic operations between two numbers. (Addition, Subtraction, Multiplication and Division)
11. Write a program to create a **dictionary** and remove one key.
12. Write a program to enter 5 subject's marks and print the grades A/B/C/D. **(loop)**
13. Write a program to print a Fibonacci sequence. **(loop)**
14. Write a program in python to plot a **graph** for the function $y = x^2$.
15. Programmes related to creating and modifying List, Tuple and Dictionary.
16. Programmes to find correlation between dependent and independent variables.
17. Programme to develop a regression model on an existing data set.

18. Programmes for data visualization (Charts using plot() function, Pie Chart, Scatter Plot, Histogram, Bar Chart)
19. Programmes for handling descriptive statistics using SciPy.
20. Solution to linear programming problems using PuLP Library.
21. Solution to deterministic EOQ based models for Inventory Management

Essential/recommended readings

- Elkner, J., Downey, A. B., & Meyers, C. (2016). *How to think like a computer scientist: learning with python*. Samurai Media Limited, United Kingdom.
- Guttag, J. V. (2013). *Introduction to computation and programming using Python*. MIT Press.
- Taneja, S., Kumar, N. Python Programming- A modular Approach, Pearson Education India, 2018.
- Deitel, P. J. (2019). P*ython Fundamentals*. Pearson.
- Dierbach, C. (2012). *Introduction to computer science using python: a computational problem-solving focus.* Wiley Publishing.
- Lambert, K. A. (2018*). Fundamentals of python: first programs*. Cengage Learning.
- Lutz, M., & Lutz, M. (1996). *Programming python* (volume 8). O'Reilly Media, Inc.
- Thareja, R. (2017). *Python programming using problem solving approach*. Oxford University Press.
- VanderPlas, J. (2016). *Python data science handbook: essential tools for working with data.* O'Reilly Media, Inc.

Suggestive readings: Nil

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

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)

Category II

DISCIPLINE SPECIFIC CORE COURSE – 3: Advanced 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		
Advanced Linear Programming DSC-3	4	3	0	1	Class XII pass with Mathematics	Basic Linear Programming

Learning Objectives

The Learning Objectives of this course are as follows:

- To enrich the knowledge of students with advanced concepts and techniques of linear programming problem along with real life applications
- To make students understand the theoretical basics of different computational algorithms used in solving linear programming and related problems.

Learning outcomes

Students completing this course will be able to:

- Explain the relationship between a linear program and its dual, including strong duality and complementary slackness, and understand the economic interpretation of duality.
- Learn an alternative method for solving linear programming problems.
- Perform sensitivity analysis to identify the direction and magnitude of change of a linear programming model's optimal solution as the input data changes.
- Formulate specialized linear programming problems, namely transportation and assignment problems and describe theoretical workings of the solution methods for transportation and assignment problems, demonstrate solution process by hand and solver.

SYLLABUS OF DSC-3

Unit I (12 Hours): Duality: Duality in linear programming, Duality theorems (Weak duality, Strong duality, Existence theorem and Complementary slackness conditions), Economic interpretation of duality, Dual simplex method.

Unit II (09 Hours): Sensitivity Analysis: Post Optimality Analysis (change in resource vector, change in cost vector, addition and deletion of a constraint, addition and deletion of a decision variable).

Unit III (15 Hours): Transportation Problem (TP): TP and its formulation, finding initial basic feasible solution of TP using North-West Corner rule, Least Cost method and Vogel's Approximation method, MODI method for finding optimal solution, Special cases in TP.

Unit IV (09 Hours): Assignment Problem (AP): AP and its formulation, Hungarian method for solving AP, Special cases in AP, Transhipment and Travelling salesmen problem.

Practical component (if any) –

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Solution to linear programming problem through dual simplex method.
2. Computational sensitivity analysis with respect to changes in the cost vector.
3. Computational sensitivity analysis with respect to changes in the resource vector.
4. Solution of transportation problem.
5. Solution of assignment problem.
6. Solution of travelling salesman problem.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J. and Sherali. H. D. (2011). *Linear Programming and Network Flows* (4th ed.). John Wiley & Sons.
- Chandra, S., Jayadeva, Mehra, A. (2009). *Numerical Optimization with Applications*. Narosa Publishing House.
- Hadley, G. (2002). *Linear Programming.* Narosa Publishing House.
- Ravindran, A., Phillips, D. T. and Solberg, J. J. (2007). *Operations Research-Principles and Practice* (2nd ed.) (WSE), John Wiley & Sons.
- Taha, H. A. (2017). *Operations Research-An Introduction* (10th ed.). Pearson.
- Winston, W. L. and Venkataramanan, M. (2002). *Introduction to Mathematical Programming: 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 – 4: 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		
Statistics DSC-4	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- The aim of this course is to acquaint the students with the fundamental concepts of Probability and Statistics, to provide an understanding of the processes by which real-life statistical problems are analysed
- To develop an understanding of the role of Statistics in Operational Research.

Learning Outcomes

Students completing this course will be able to:

- Quantify uncertainty using probability, learn how to find probability using the concepts of random variables and distribution functions, obtain characteristics of the underlying distributions, and study functional relationships between two random variables.
- Know various discrete and continuous probability distributions along with their characteristics and identify the situations where they provide realistic models.
- Know about the modes of convergence in probability theory.
- Define the functional relationship between two variables and gain a foothold in basic concepts of forecasting.

SYLLABUS OF DSC-4

Unit I (6 Hours): Probability: Probability Axioms, Conditional Probability and Bayes' Theorem and its Applications.

Unit II (15 hours): Random Variables, Distribution Functions, and Moments: Expectation and Variance, Moment Generating Functions and Characteristic Function, Multidimensional Random Variable, Conditional Expectation and Conditional Variance. Joint, Marginal and Conditional Distributions. Independent Random Variables.

Unit III (15 Hours): Probability Distributions and Large Sample Theory:
Discrete and Continuous Probability Distributions (Binomial, Poisson, Geometric Negative binomial, Uniform, Exponential, Normal), Weak Law of Large Numbers, Strong Law of Large Numbers. Central Limit Theorem.

Unit IV (09 Hours): Regression and Forecasting: Karl Pearson's Coefficient of Correlation, Lines of regression, Introduction to Forecasting.

Practical component (if any) -

1. Practicals to Analyse frequency distribution using moments.
2. Practicals to demonstrate applications of Binomial, Poisson and Normal Distributions
3. Practicals to understand Fitting of discrete distributions-Binomial, Poisson, Negative Binomial
4. Fitting of continuous distributions-Exponential. Normal
5. Finding Karl Pearson's Correlation Coefficient using raw and grouped data
6. Analysis of data to be used for forecasting- graphically, using summary statistics, and various measures of forecasting accuracy that are used to help judge the appropriateness of a model
7. Regression Analysis and forecasting using Lines of regression

Essential/recommended readings

- Makridakis, S., Wheelwright, S. C., & Hyndman, R. J. (2008). *Forecasting methods and applications*. John wiley & sons.
- Devore, J. L. (2012). *Probability and Statistics for Engineering and the Sciences* (8th ed.) Cengage Learning.
- Feller, W. (2008). *An Introduction to Probability Theory and its Applications - Vol I* (3rd ed.). Wiley.
- Gupta, S.C, Kapoor, V K (2020). *Fundamentals of Mathematical Statistics* (12th Ed.) Sultan Chand and Sons.
- Hogg, R.V., Craig, A.T., and Mckean, J.W. (2019). *Introduction to Mathematical Statistics* (8th ed.). Pearson.
- Rohatgi, V. K., & Saleh, A. K. E. Md. (2015). *An Introduction to Probability and Statistics* (3nd ed.). Wiley.
- Ross, S. (2014). *Introduction to Probability Models* (11th ed.). Academic Press/Elsevier.

Suggestive readings: Nil

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)

Category III

DISCIPLINE SPECIFIC CORE COURSE – 3: Advanced 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		
Advanced Linear Programming DSC-3	4	3	0	1	Class XII pass with Mathematics	Basic Linear Programming

Learning Objectives

The Learning Objectives of this course are as follows:

- To enrich the knowledge of students with advanced concepts and techniques of linear programming problem along with real life applications
- To make students understand the theoretical basics of different computational algorithms used in solving linear programming and related problems.

Learning outcomes

Students completing this course will be able to:

- Explain the relationship between a linear program and its dual, including strong duality and complementary slackness, and understand the economic interpretation of duality.
- Learn an alternative method for solving linear programming problems.
- Perform sensitivity analysis to identify the direction and magnitude of change of a linear programming model's optimal solution as the input data changes.
- Formulate specialized linear programming problems, namely transportation and assignment problems and describe theoretical workings of the solution methods for transportation and assignment problems, demonstrate solution process by hand and solver.

SYLLABUS OF DSC-3

Unit I (12 Hours): Duality: Duality in linear programming, Duality theorems (Weak duality, Strong duality, Existence theorem and Complementary slackness conditions), Economic interpretation of duality, Dual simplex method.

Unit II (09 Hours): Sensitivity Analysis: Post Optimality Analysis (change in resource vector, change in cost vector, addition and deletion of a constraint, addition and deletion of a decision variable).

Unit III (15 Hours): Transportation Problem (TP): TP and its formulation, finding initial basic feasible solution of TP using North-West Corner rule, Least Cost method and Vogel's Approximation method, MODI method for finding optimal solution, Special cases in TP.

Unit IV (09 Hours): Assignment problem (AP): AP and its formulation, Hungarian method for solving AP, Special cases in AP, Transhipment and Travelling salesmen problem.

Practical component (if any) –

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Solution to linear programming problem through dual simplex method.
2. Computational sensitivity analysis with respect to changes in the cost vector.
3. Computational sensitivity analysis with respect to changes in the resource vector.
4. Solution of transportation problem.
5. Solution of assignment problem.
6. Solution of travelling salesman problem.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J. and Sherali. H. D. (2011). *Linear Programming and Network Flows* (4th ed.). John Wiley & Sons.
- Chandra, S., Jayadeva, Mehra, A. (2009). *Numerical Optimization with Applications*. Narosa Publishing House.
- Hadley, G. (2002). *Linear Programming.* Narosa Publishing House.
- Ravindran, A., Phillips, D. T. and Solberg, J. J. (2007). *Operations Research-Principles and Practice* (2nd ed.) (WSE), John Wiley & Sons.
- Taha, H. A. (2017). *Operations Research-An Introduction* (10th ed.). Pearson.
- Winston, W. L. and Venkataramanan, M. (2002). *Introduction to Mathematical Programming: 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.

BSc. (Physical Sciences/ Mathematical Sciences) with Operational Research as one of the Core Disciplines

Category IV

DISCIPLINE SPECIFIC CORE COURSE – 3: Advanced 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		
Advanced Linear Programming DSC-3	4	3	0	1	Class XII pass with Mathematics	Basic Linear Programming

Learning Objectives

The Learning Objectives of this course are as follows:

- To enrich the knowledge of students with advanced concepts and techniques of linear programming problem along with real life applications
- To make students understand the theoretical basics of different computational algorithms used in solving linear programming and related problems.

Learning outcomes

Students completing this course will be able to:

- Explain the relationship between a linear program and its dual, including strong duality and complementary slackness, and understand the economic interpretation of duality.
- Learn an alternative method for solving linear programming problems.
- Perform sensitivity analysis to identify the direction and magnitude of change of a linear programming model's optimal solution as the input data changes.
- Formulate specialized linear programming problems, namely transportation and assignment problems and describe theoretical workings of the solution methods for transportation and assignment problems, demonstrate solution process by hand and solver.

SYLLABUS OF DSC-3

Unit I (12 Hours): Duality: Duality in linear programming, Duality theorems (Weak duality, Strong duality, Existence theorem and Complementary slackness conditions), Economic interpretation of duality, Dual simplex method.

Unit II (09 Hours): Sensitivity Analysis: Post Optimality Analysis (change in resource vector, change in cost vector, addition and deletion of a constraint, addition and deletion of a decision variable).

Unit III (15 Hours): Transportation Problem (TP): TP and its formulation, finding initial basic feasible solution of TP using North-West Corner rule, Least Cost method and Vogel's Approximation method, MODI method for finding optimal solution, Special cases in TP.

Unit IV (09 Hours): Assignment problem (AP): AP and its formulation, Hungarian method for solving AP, Special cases in AP, Transhipment and Travelling salesmen problem.

Practical component (if any) –

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Solution to linear programming problem through dual simplex method.
2. Computational sensitivity analysis with respect to changes in the cost vector.
3. Computational sensitivity analysis with respect to changes in the resource vector.
4. Solution of transportation problem.
5. Solution of assignment problem.
6. Solution of travelling salesman problem.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J. and Sherali. H. D. (2011). *Linear Programming and Network Flows* (4th ed.). John Wiley & Sons.
- Chandra, S., Jayadeva, Mehra, A. (2009). *Numerical Optimization with Applications*. Narosa Publishing House.
- Hadley, G. (2002). *Linear Programming.* Narosa Publishing House.
- Ravindran, A., Phillips, D. T. and Solberg, J. J. (2007). *Operations Research-Principles and Practice* (2nd ed.) (WSE), John Wiley & Sons.
- Taha, H. A. (2017). *Operations Research-An Introduction* (10th ed.). Pearson.
- Winston, W. L. and Venkataramanan, M. (2002). *Introduction to Mathematical Programming: 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 Generic Electives (GE) Courses offered by Department of Operational Research

GENERIC ELECTIVES (GE-2): Production and Inventory 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
		Lecture	Tutorial	Practical/ Practice		
Production and Inventory Management GE-2	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives

The objective of this course is to introduce fundamental concepts in production and inventory management and at the same time, develop the students' modelling and analytical skills.

Learning outcomes

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of key concepts of Production and Inventory management and its role in various organizations.
- Apply selective inventory control techniques and understand its significance.
- Determine optimal order quantity for various deterministic and probabilistic inventory models.
- Understand quantity discount models in inventory management.
- Formulate and develop Production Planning and Scheduling models.
- To apply and extend production and inventory models to analyse real world systems.

SYLLABUS OF GE-2

Unit I (9 Hours): Production and Inventory Management, Introduction , Different types of costs in inventory system, Selective inventory classification (VED, XML, FNSD, ABC) and its use in controlling inventory.

Unit II (15 Hours): Deterministic continuous review models: Economic order quantity (EOQ) model with and without shortages, Finite replenishment rate Inventory models without and with planned shortages. Determination of reorder point, Quantity discount models.
Unit III (9 Hours): Probabilistic inventory models: Single period probabilistic inventory models with discrete and continuous demand.
Unit IV (12 Hours): Production Planning and Scheduling,:Introduction, Aggregate production plan, Formulation of lot size production problem: Wagner and Within algorithm. Basic concepts of Just-in-Time (JIT) and Material Requirement Planning (MRP).

Practical component (if any) -

Practical/Lab to be performed on a computer using OR/Statistical packages

1. Problems based on selective inventory classification. (ABC and FNS analysis)
2. To find optimal inventory policy for EOQ model.
3. To find optimal inventory policy for EOQ model with finite supply.
4. To find optimal inventory policy for EOQ model with backorders.
5. To solve all units quantity discounts model.
6. To solve Incremental quantity discount model
7. To find optimal inventory policy for Probabilistic inventory model with discrete demand.
8. To find optimal inventory policy for Probabilistic inventory model with continuous.
9. Solution of procurement/production scheduling model.

Essential/recommended readings

- Axsäter, S. (2015). *Inventory control* (3rd Edition). Springer.
- Buffa, Elwood S., & Sarin, Rakesh, K. (2009). *Modern Production/Operations Management* (8th ed.). Wiley, India.
- Hadley, G., & Whitin, T. M. (1963). *Analysis of inventory systems*. Prentice-Hall.
- Heizer, J., & Render, B. (2011). *Operations Management* (10th ed.). Pearson's Publication.
- Johnson, L.A., & Montgomery, D.C. (1974) *Operations Research in Production Planning, Scheduling and Inventory Control*. Wiley, New York.
- Waters, D. (2008). Inventory control and management. (2nd ed.). John Wiley & Sons.

Suggestive readings

- Naddor, E. (1966). *Inventory Systems*. Wiley.
- Silver, E. A., Pyke, D. F., & Peterson, R. (1998). Inventory management and production planning and scheduling (3rd ed.). Wiley.

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

DEPARTMENT OF COMPUTER SCIENCE

BSc. (Hons.) Computer Science -DSC

Category I

DISCIPLINE SPECIFIC CORE COURSE – 4: Object Oriented 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		
DSC04 Object Oriented Programming with C++	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives

This course is designed to introduce programming concepts using C++ to students. The course aims to develop structured as well as object-oriented programming skills using C++ programming language. The course also aims to achieve competence amongst its students to develop correct and efficient C++ programs to solve problems spanning multiple domains.

Learning outcomes

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

- Write simple programs using built-in data types of C++.
- Implement arrays and user defined functions in C++.
- Write programs using dynamic memory allocation, handling external files, interrupts and exceptions.
- Solve problems spanning multiple domains using suitable programming constructs in C++.
- Solve problems spanning multiple domains using the concepts of object oriented programming in C++.

SYLLABUS OF DSC-4

UNIT – I (3 Hours)

Introduction to C++: Overview of Procedural and Object-Oriented Programming, Using main() function, Header Files, Compiling and Executing Simple Programs in C++

UNIT – II (12 Hours)

Programming Fundamentals: Data types, Variables, Operators, Expressions, Arrays, Keywords, Decision making constructs, Iteration, Type Casting, Input-output statements, Functions, Command Line Arguments/Parameters

UNIT – III (15 Hours)

Object Oriented Programming: Concepts of Abstraction, Encapsulation. Creating Classes and objects, Modifiers and Access Control, Constructors, Destructors, Implementation of Inheritance and Polymorphism, Template functions and classes

UNIT – IV (9 Hours)

Pointers and References: Static and dynamic memory allocation, Pointer and Reference Variables, Implementing Runtime polymorphism using pointers and references

UNIT – V (6 Hours)

Exception and File Handling: Using try, catch, throw, throws and finally; Nested try, creating user defined exceptions, File I/O Basics, File Operations

Practical component (if any) -30 Hours

1. Write a program to compute the sum of the first n terms of the following series:

   $sum = 1 - \frac{1}{2^2} + \frac{1}{3^3} -$ . . . .

   The number of terms n is to be taken from the user through the command line. If the command line argument is not found then prompt the user to enter the value of n.
2. Write a program to remove the duplicates from an array.
3. Write a program that prints a table indicating the number of occurrences of each alphabet in the text entered as command line arguments.
4. Write a menu driven program to perform string manipulation (without using inbuilt string functions):
   a. Show address of each character in string
   b. Concatenate two strings.
   c. Compare two strings
   d. Calculate length of the string (use pointers)
   e. Convert all lowercase characters to uppercase
   f. Reverse the string
   g. Insert a string in another string at a user specified position
5. Write a program to merge two ordered arrays to get a single ordered array.

6. Write a program to search a given element in a set of N numbers using Binary search

   (i) with recursion (ii) without recursion.

7. Write a program to calculate GCD of two numbers (i) with recursion (ii) without recursion.

8. Create a Matrix class. Write a menu-driven program to perform following Matrix operations (exceptions should be thrown by the functions if matrices passed to them are incompatible and handled by the main() function):

   a. Sum

   b. Product

   c. Transpose

9. Define a class Person having name as a data member. Inherit two classes Student and Employee from Person. Student has additional attributes as course, marks and year and Employee has department and salary. Write display() method in all the three classes to display the corresponding attributes. Provide the necessary methods to show runtime polymorphism.

10. Create a Triangle class. Add exception handling statements to ensure the following conditions: all sides are greater than 0 and sum of any two sides are greater than the third side. The class should also have overloaded functions for calculating the area of a right angled triangle as well as using Heron's formula to calculate the area of any type of triangle.

11. Create a class Student containing fields for Roll No., Name, Class, Year and Total Marks. Write a program to store 5 objects of Student class in a file. Retrieve these records from the file and display them.

12. Copy the contents of one text file to another file, after removing all whitespaces.

Essential/recommended readings

1. Stephen Prata, *C++ Primer Plus*, 6th Edition, Pearson India, 2015.
2. E Balaguruswamy, *Object Oriented Programming with C++*, 8th edition, McGraw-Hill Education, 2020.
3. D.S. Malik, *C++ Programming: From Problem Analysis to Program Design*, 6th edition, Cengage Learning, 2013.

Suggestive readings

(i) Schildt, H. *C++: The Complete Reference*, 4th edition, McGraw Hill, 2003

(ii) Forouzan, A. B., Gilberg, R. F. *Computer Science: A Structured Approach using C++,* 2nd edition, Cengage Learning, 2010

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

DISCIPLINE SPECIFIC CORE COURSE – 5: Discrete Mathematical 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC 05 Discrete Mathematical Structures	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**Nil**

Learning Objectives

This course is designed as a foundational course to make students learn about the mathematical constructs that are used in Computer Science such as Boolean algebra, sets, relations, functions, principles of counting, and recurrences. In this course, the knowledge of mathematical notation, ideas and concepts learnt at the pre-college levels is extended to orient the students towards mathematical thinking required in Computer Science.

Learning outcomes

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

- Relate mathematical concepts and terminology to examples in the domain of Computer Science.
- Model real world problems using various mathematical constructs.
- Use different proofing techniques; construct simple mathematical proofs using logical arguments.
- Formulate mathematical claims and construct counterexamples.

SYLLABUS OF DSC- 5
UNIT – I (06 Hours)
Sets, Functions, Sequences and Summations, Relations: Sets: Set Operations, Computer Representation of Sets, Countable and Uncountable Set, Principle of Inclusion and Exclusion, Multisets; Functions: One-to-one and Onto Functions, Inverse Functions and Compositions of

Functions, Graphs of Functions Sequences and Summations: Sequences, Special Integer Sequences, Summations; Relations: Properties of Binary Relations, Equivalence relations and Partitions, Partial Ordering Relations and Lattices.

UNIT – II (09 Hours)

Logic and Proofs: Propositional Logic, Propositional Equivalences, Use of first-order logic to express natural language predicates, Quantifiers, Nested Quantifiers, Rules of Inference, Introduction to Proofs, Proof Methods and Strategies, Mathematical Induction.

UNIT – III (09 Hours)

Number Theory: Division and Integers, Primes and Greatest Common Divisors, Representation of Integers, Algorithms for Integer Operations, Modular Exponentiation, Applications of Number Theory.

UNIT – IV (06 Hours)

Combinatorics/Counting: The Pigeonhole Principle, Permutations and Combinations, Binomial Coefficients, Generalized Permutations and Combinations, Generating Permutations and Combinations.

UNIT – V (09 Hours)

Graphs and Trees: Graphs: Basic Terminology, Multigraphs and Weighted Graphs, Paths and Circuits, Eulerian Paths and Circuits, Hamiltonian paths and Circuits, Shortest Paths, Spanning Trees, Graph Isomorphism, Planar Graphs; Trees: Trees, Rooted Trees, Path Lengths in Rooted Trees.

UNIT – VI (06 Hours)

Recurrence: Recurrence Relations, Generating Functions, Linear Recurrence Relations with Constant Coefficients and their solution.

Practical component (if any) – 30 Hours

1. Create a class SET. Create member functions to perform the following SET operations:
    1) is member: check whether an element belongs to the set or not and return value as true/false.
    2) powerset: list all the elements of the power set of a set .
    3) subset: Check whether one set is a subset of the other or not.
    4) union and Intersection of two Sets.
    5) complement: Assume Universal Set as per the input elements from the user.
    6) set Difference and Symmetric Difference between two sets.
    7) cartesian Product of Sets.

    Write a menu driven program to perform the above functions on an instance of the SET class.

2. Create a class RELATION, use Matrix notation to represent a relation. Include member functions to check if the relation is Reflexive, Symmetric, Anti-symmetric, Transitive. Using these functions check whether the given relation is: Equivalence or Partial Order relation or None

3. Write a Program that generates all the permutations of a given set of digits, with or without repetition.
4. For any number n, write a program to list all the solutions of the equation $x_1 + x_2 + x_3 + ...+ x_n = C$, where C is a constant (C<=10) and $x_1, x_2, x_3, ..., x_n$ are nonnegative integers, using brute force strategy.
5. Write a Program to evaluate a polynomial function. (For example store $f(x) = 4n^2 + 2n + 9$ in an array and for a given value of n, say n = 5, compute the value of f(n)).
6. Write a Program to check if a given graph is a complete graph. Represent the graph using the Adjacency Matrix representation.
7. Write a Program to check if a given graph is a complete graph. Represent the graph using the Adjacency List representation.
8. Write a Program to accept a directed graph G and compute the in-degree and out-degree of each vertex.

Essential/recommended readings

1. Liu, C. L., Mohapatra, D. P. *Elements of Discrete Mathematics: A Computer Oriented Approach*, 4th edition, Tata McGraw Hill, 2017.
2. Rosen, K. H.. *Discrete Mathematics and Its Applications*, 8th edition, McGraw Hill, 2018.

Suggestive readings

(i) Cormen, T. H., Leiserson, C. E., Rivest, R. L., Stein C. *Introduction to Algorithms*, 4th edition, Prentice Hall of India. 2022.
(ii) Trembley, J. P., Manohar, R. *Discrete Mathematical Structures with Application to Computer Science*, Tata McGraw Hill, 1997.
(iii) Albertson, M. O. and Hutchinson, J. P. *Discrete Mathematics with Algorithms*, John Wiley and Sons, 1988.

DISCIPLINE SPECIFIC CORE COURSE – 6: Probability for 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC06 Probability for computing	**4**	**3**	**0**	**1**	Class XII pass with Mathematics	**Nil**

Learning Objectives

This course introduces the students to the fundamental concepts and topics of probability and statistics, whose knowledge is important in other computer science courses. The course aims to build the foundation for some of the core courses in later semesters.

Learning outcomes

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

- Use probability theory to evaluate the probability of real-world events.
- Describe discrete and continuous probability distribution functions and generate random numbers from the given distributions.
- Find the distance between two probability distributions
- Define and quantify the information contained in the data.
- Perform data analysis in a probabilistic framework.
- Visualize and model the given problem using mathematical concepts covered in the course.

SYLLABUS OF DSC-6 UNIT-I (09 Hours)

Basic Probability: Introduction to the notion of probability, Random experiment, Sample space and Events, Probability defined on events, Algebra of events. Conditional probabilities, independent events, Bayes' theorem.

UNIT-II (12 Hours)

Random Variables: Introduction to Random Variables, Probability mass/density functions, Cumulative distribution functions. Discrete Random Variables (Bernoulli, Binomial, Poisson, Multinomial and Geometric). Continuous Random Variables (Uniform, Exponential and Normal). Expectation of a Random Variable, Expectation of Function of a Random Variable and Variance. Markov inequality, Chebyshev's inequality, Central Limit Theorem, Weak and Strong Laws of Large Numbers.

UNIT-III (09 Hours)

Joint Distributions: Jointly distributed Random Variables, Joint distribution functions, Independent Random Variables, Covariance of Random Variables, Correlation Coefficients,

Conditional Expectation.

UNIT-IV (15 Hours)

Markov Chain and Information Theory: Introduction to Stochastic Processes, Chapman–Kolmogorov equations, Classification of states, Limiting and Stationary Probabilities. Random Number Generation, Pseudo Random Numbers, Inverse Transformation Method, Rejection Method, Uncertainty, Information and Entropy, Mutual Information, KL Divergence.

Practical component (if any) – 30 Hours

The goal of this lab is to develop data interpretation skills. Following exercises are designed to enable students to understand data characteristics either by visualization or by interpreting computed measures. All the exercises are to be completed using MS Excel functions and graphs. At the end of each exercise, the student should be able to draw a conclusion and state in a concise manner. Teachers are expected to guide students to obtain real data available through the internet for the following exercises.

1. Plotting and fitting of Binomial distribution and graphical representation of probabilities.
2. Plotting and fitting of Multinomial distribution and graphical representation of probabilities.
3. Plotting and fitting of Poisson distribution and graphical representation of probabilities.
4. Plotting and fitting of Geometric distribution and graphical representation of probabilities.
5. Plotting and fitting of Uniform distribution and graphical representation of probabilities.
6. Plotting and fitting of Exponential distribution and graphical representation of probabilities.
7. Plotting and fitting of Normal distribution and graphical representation of probabilities.
8. Calculation of cumulative distribution functions for Exponential and Normal distribution.
9. Given data from two distributions, find the distance between the distributions.
10. Application problems based on the Binomial distribution.
11. Application problems based on the Poisson distribution.
12. Application problems based on the Normal distribution.
13. Presentation of bivariate data through scatter-plot diagrams and calculations of covariance.
14. Calculation of Karl Pearson's correlation coefficients.
15. To find the correlation coefficient for a bivariate frequency distribution.
16. Generating Random numbers from discrete (Bernoulli, Binomial, Poisson) distributions.

17. Generating Random numbers from continuous (Uniform, Normal) distributions.
18. Find the entropy from the given data set.

Essential/recommended readings

1. Ross **S**heldon M. *Introduction to Probability Models*, 12th Edition, Elsevier, 2019.
2. Trivedi, K. S. *Probability and Statistics with Reliability, Queuing and Computer Science Applications*, 2nd edition, Wiley, 2015.
3. Deisenroth, Marc Peter, Faisal A. Aldo and Ong Cheng Soon, *Mathematics for Machine Learning*, 1st edition, Cambridge University Press, 2020.
4. Ian F. Blake, *An Introduction to Applied Probability*, John Wiley.

Suggestive readings

(i) Johnson James L., *Probability and Statistics for Computer Science*, 6th edition, Wiley, 2004.

(ii) Forsyth David, *Probability and Statistics for Computer Science*, 1st edition, Springer, 2019.

(iii) Freund J.E., *Mathematical Statistics with Applications*, 8th edition, Pearson Education, 2013.

(iv) Devore Jay L., *Probability and Statistics for Engineering and the Sciences*, 9th edition, Cengage Learning, 2020.

BSc. (Physical Sciences/ Mathematical Sciences) with Computer Science as one of the Core Disciplines

Category II

DISCIPLINE SPECIFIC CORE COURSE (DSC-2): 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC02: Data Structures using C++	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	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 DSC-2 UNIT – I (06 Hours)

Growth of Functions, Recurrence Relations. Functions used in analysis, asymptotic notations, asymptotic analysis, solving recurrences using recursion tree, Master Theorem.

UNIT – II (12 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 – III (06 Hours)

Sorting: Insertion Sort, Count Sort and their complexity analysis.

UNIT – IV (03 Hours)

Recursion: Recursive functions, linear recursion, binary recursion.

UNIT – V (06 Hours)

Trees, Binary Trees. Trees: definition and properties, binary trees: definition and properties, traversal of binary trees and their time complexity analysis.

UNIT – VI (09 Hours)

Binary Search Trees, Balanced Search Trees: Binary Search Trees: insert, delete (by copying), search operations, time complexity analysis of these operations; Balanced Search Trees and (2,4) Trees: motivation and introduction.

UNIT – VII (03 Hours)

Binary Heap, Priority Queue: Binary Heaps: motivation and introduction, application of heaps - Priority Queues.

Practical component (if any) – 30 Hours

1. Perform matrix addition and multiplication.
2. Implement following recursive functions:
    a. Factorial of a number
    b. N^{th} fibonacci number
    c. Power function: x^y
3. Implement singly linked lists.
4. Implement doubly linked lists.
5. Implement circular linked lists.
6. Implement stack data structure and its operations using arrays.
7. Implement stack data structure and its operations using linked lists.
8. Convert Prefix expression to Infix and Postfix expressions, and evaluate.
9. Implement queue data structure and its operations using arrays.
10. Implement queue data structure and its operations using linked lists.
11. Implement Binary Trees and its traversals.

Essential/recommended readings

1. Goodrich, M., 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*, 3rd edition, Prentice Hall of India, 2010.
3. Drozdek, A., *Data Structures and Algorithms in C++*, 4th edition, Cengage Learning, 2012.

Suggestive readings

(i) Sahni, S. *Data Structures, Algorithms and applications in C++*. 2nd Edition. Universities Press, 2011.

(ii)Tanenbaum, A. M., Augenstein, M. J., & Langsam Y., *Data Structures Using C and C++*. 2nd edition. Prentice Hall of India, 2009.

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

BA (Prog.) with Computer Science as Major

Category III

DISCIPLINE SPECIFIC CORE COURSE (DSC-2): 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC02: Data Structures	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	Nil

Learning Objectives

The course aims at developing the ability to define, differentiate, implement the basic data structures like arrays, stacks, queues, lists, trees and use them 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:

- Understand abstract specification of data-structures.
- Implement data structures as ADT..
- Identify the appropriate data structure(s) for a given application.
- Apply recursive techniques to solve problems.

SYLLABUS OF DSC-2

UNIT – I (15 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.

UNIT – II (06 Hours)

Searching and Sorting: Linear Search, Binary Search, Insertion Sort, Count Sort.

UNIT – III (09 Hours)

Recursion: Recursive functions, linear recursion, binary recursion.

UNIT – IV (06 Hours)

Trees, Binary Trees: Trees: definition and properties, binary trees: definition and properties, traversal of binary trees.

UNIT – V(09 Hours)

Binary Search Trees: insert, delete (by copying), search operations.

Practical component (if any) – 30 Hours

1. Perform matrix addition and multiplication.
2. Implement following recursive functions:

   Factorial of a number

   N^{th} fibonacci number

   Power function: x^y
3. Implement singly linked lists.
4. Implement doubly linked lists.
5. Implement circular linked lists.
6. Implement stack data structure and its operations using arrays.
7. Implement stack data structure and its operations using linked lists.
8. Convert Prefix expression to Infix and Postfix expressions, and evaluate.
9. Implement queue data structure and its operations using arrays.
10. Implement queue data structure and its operations using linked lists.
11. Implement Binary Trees and its traversals.

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. Drozdek, A. *Data Structures and Algorithms in C++*, 4th edition, Cengage Learning, 2012.

Suggestive readings

(i) Sahni, S., *Data Structures, Algorithms and applications in C++*, 2nd edition, Universities Press, 2011.

(ii) Langsam Y., Augenstein, M. J., & Tanenbaum, A. M. *Data Structures Using C and C++*, Pearson, 2009.

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

DISCIPLINE SPECIFIC CORE COURSE – A2 : DATA INTERPRETATION AND VISUALIZATION USING 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		
A2: Data Interpretation and Visualization using Python	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	knowledge of Python

Learning Objectives

This course is designed to introduce the students to the application of Python to get a deterministic view of data and interpret results..

Learning outcomes

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

- Interpret Data
- Obtain a deterministic view of data
- Perform data handling using Numpy arrays
- Load, clean, transform, merge and reshape data using Pandas
- Visualize data using Pandas and matplot libraries

SYLLABUS OF A2

UNIT – I (06 Hours)

Introduction to basic statistics and analysis: Fundamentals of Data Analysis, Statistical foundations for Data Analysis, Types of data, Descriptive Statistics, Correlation and covariance, Linear Regression, Statistical Hypothesis Generation and Testing, Python Libraries: NumPy, Pandas, Matplotlib

UNIT – II (09 Hours)

Array manipulation using Numpy: Numpy array: Creating Numpy arrays; various data types of Numpy arrays, indexing and slicing, swapping axes, transposing arrays, data processing using Numpy arrays

UNIT – III (12 Hours)

Data Manipulation using Pandas: Data Structures in Pandas: Series, DataFrame, Index objects, Loading data into Pandas data frame, Working with Data Frames: Arithmetics, Statistics, Binning, Indexing, Reindexing, Filtering, Handling missing data, Hierarchical indexing, Data wrangling: Data cleaning, transforming, merging and reshaping

UNIT – IV (12 Hours)

Plotting and Visualization: Using Matplotlib to plot data: figures, subplots, markings, color and line styles, labels and legends, plotting functions in Pandas: Line, bar, Scatter plots, histograms, stacked bars, Heatmap

UNIT-V (06 Hours)

Data Aggregation and Group operations: Group by Mechanics, Data aggregation, General split-apply-combine, Pivot tables and cross tabulation.

Practical component (if any) – 30 Hours

Use a dataset of your choice from Open Data Portal (https:// data.gov.in/, UCI repository) or load from scikit, seaborn library for the following exercises to practice the concepts learnt.

1. Load a Pandas dataframe with a selected dataset. Identify and count the missing values in a dataframe. Clean the data after removing noise as follows
   a. Drop duplicate rows.
   b. Detect the outliers and remove the rows having outliers
   c. Identify the most correlated positively correlated attributes and negatively correlated attributes
2. Import iris data using sklearn library or (Download IRIS data from: https://archive.ics.uci.edu/ml/datasets/iris or import it from sklearn.datasets)

i. Compute mean, mode, median, standard deviation, confidence interval and standard error for each feature
ii. Compute correlation coefficients between each pair of features and plot heatmap
iii. Find covariance between length of sepal and petal
iv. Build contingency table for class feature

3. Load Titanic data from sklearn library, plot the following with proper legend and axis labels:

a. Plot bar chart to show the frequency of survivors and non-survivors for male and female passengers separately
b. Draw a scatter plot for any two selected features
c. Compare density distribution for features age and passenger fare
d. Use a pair plot to show pairwise bivariate distribution

4. Using Titanic dataset, do the following
a. Find total number of passengers with age less than 30
b. Find total fare paid by passengers of first class
c. Compare number of survivors of each passenger class

5. Download any dataset and do the following
a. Count number of categorical and numeric features
b. Remove one correlated attribute (if any)
c. Display five-number summary of each attribute and show it visually

Essential/recommended readings

1. McKinney W. *Python for Data Analysis: Data Wrangling with Pandas, NumPy and IPython*, 2nd edition, O'Reilly Media, 2018.
2. Molin S. *Hands-On Data Analysis with Pandas*, Packt Publishing, 2019.
3. Gupta S.C., Kapoor V.K. *Fundamentals of Mathematical Statistics*,12th edition, Sultan Chand & Sons, 2020.

Suggestive readings

(i) Chen D. Y. *Pandas for Everyone: Python Data Analysis*, 1st edition, Pearson Education, 2018.

(ii) Miller J.D. *Statistics for Data Science,* Packt Publishing Limited, 2017.

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

BA (Prog.) with Computer Science as Non-Major

Category III

DISCIPLINE SPECIFIC CORE COURSE (DSC-2): 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC02: Data Structures	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	Knowledge of C++

Learning Objectives

The course aims at developing the ability to define, differentiate, implement the basic data structures like arrays, stacks, queues, lists, trees and use them 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:

- Understand abstract specification of data-structures.
- Implement data structures as ADT..
- Identify the appropriate data structure(s) for a given application.
- Apply recursive techniques to solve problems.

SYLLABUS OF DSC-2

UNIT – I (15 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.

UNIT – II (06 Hours)

Searching and Sorting: Linear Search, Binary Search, Insertion Sort, Count Sort.

UNIT – III (09 Hours)

Recursion: Recursive functions, linear recursion, binary recursion.

UNIT – IV (06 Hours)

Trees, Binary Trees: Trees: definition and properties, binary trees: definition and properties, traversal of binary trees.

UNIT – V (09 Hours)

Binary Search Trees: insert, delete (by copying), search operations.

Practical component (if any) – 30 Hours

1. Perform matrix addition and multiplication.
2. Implement following recursive functions:
    i. Factorial of a number
    ii. N^{th} fibonacci number
    iii. Power function: x^y
3. Implement singly linked lists.
4. Implement doubly linked lists.
5. Implement circular linked lists.
6. Implement stack data structure and its operations using arrays.
7. Implement stack data structure and its operations using linked lists.
8. Convert Prefix expression to Infix and Postfix expressions, and evaluate.
9. Implement queue data structure and its operations using arrays.
10. Implement queue data structure and its operations using linked lists.
11. Implement Binary Trees and its traversals.

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. Drozdek, A. *Data Structures and Algorithms in C++*, 4th edition, Cengage Learning, 2012.

Suggestive readings

(i) Sahni, S., *Data Structures, Algorithms and applications in C++*, 2nd edition, Universities Press, 2011.

(ii) Langsam Y., Augenstein, M. J., & Tanenbaum, A. M. *Data Structures Using C and C++*, Pearson, 2009.

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 Computer Sciences
Category-IV

GENERIC ELECTIVES (GE-2a): Data Analysis and Visualization

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		
GE2a Data Analysis and Visualization using Python	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	knowledge of Python

Learning Objectives

This course is designed to introduce the students to real-world data analysis problems, their analysis and interpretation of results in the field of exploratory data science using Python.

Learning outcomes

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

- Apply descriptive statistics to obtain a deterministic view of data
- Apply basic and advanced level statistical function on data
- Perform data handling using Numpy arrays
- Do data cleaning and transformation before extracting useful information
- Visualize data for ease of understanding the revealed information

SYLLABUS OF GE-2a

UNIT – I & II (09 Hours)

Introduction to basic statistics and analysis: Fundamentals of Data Analysis, Statistical foundations for Data Analysis, Types of data, Descriptive Statistics, Python Libraries: NumPy, Pandas, Matplotlib

Array manipulation using NumPy: NumPy array: Creating NumPy arrays, various data types of NumPy arrays

UNIT – I & II (09 Hours)

Introduction to basic statistics and analysis: contd..

Correlation and covariance, Linear Regression, Statistical Hypothesis Generation and Testing

Unit 2 Array manipulation using Numpy: contd..

Indexing and slicing, swapping axes, transposing arrays, data processing using Numpy arrays

UNIT – III (15 Hours)

Data Manipulation using Pandas: Data Structures in Pandas: Series, Data Frame, Index objects, loading data into Panda's data frame, Working with Data Frames: Arithmetics, Statistics, Binning, Indexing, Reindexing, Filtering, Handling missing data, Hierarchical indexing, Data wrangling: Data cleaning, transforming, merging and reshaping

UNIT – IV (12 Hours)

Plotting and Visualization: Using Matplotlib to plot data: figures, subplots, markings, color and line styles, labels and legends, Plotting functions in Pandas: Lines, bar, Scatter plots, histograms, stacked bars, Heatmap

Practical component (if any) – 30 Hours

Use data set of your choice from Open Data Portal (https:// data.gov.in/, UCI repository) or load from scikit, seaborn library for the following exercises to practice the concepts learnt.

1. Load a Pandas data frame with a selected dataset. Identify and count the missing values in a data frame. Clean the data after removing noise as follows
   a. Drop duplicate rows.
   b. Detect the outliers and remove the rows having outliers
   c. Identify the most correlated positively correlated attributes and negatively correlated attributes
2. Import iris data using sklearn library or (Download IRIS data from: https://archive.ics.uci.edu/ml/datasets/iris or import it from sklearn.datasets)
   a. Compute mean, mode, median, standard deviation, confidence interval and standard error for each feature
   b. Compute correlation coefficients between each pair of features and plot heatmap
   c. Find covariance between length of sepal and petal
   d. Build contingency table for class feature
3. Load Titanic data from sklearn library , plot the following with proper legend and axis labels:
   a. Plot bar chart to show the frequency of survivors and non-survivors for male and female passengers separately
   b. Draw a scatter plot for any two selected features
   c. Compare density distribution for features age and passenger fare

d. Use a pair plot to show pairwise bivariate distribution

4. Using Titanic dataset, do the following
   a. Find total number of passengers with age less than 30
   b. Find total fare paid by passengers of first class
   c. Compare number of survivors of each passenger class

Project students are encouraged to work on a good dataset in consultation with their faculty and apply the concepts learned in the course.

Essential/recommended readings

1. McKinney W. *Python for Data Analysis: Data Wrangling with Pandas*, *NumPy and IPython*. 2nd edition, O'Reilly Media, 2018.
2. Molin S. *Hands-On Data Analysis with Pandas*, Packt Publishing, 2019.
3. Gupta S.C., Kapoor V.K., *Fundamentals of Mathematical Statistics*, Sultan Chand & Sons, 2020.

Suggestive readings

(i) Chen D. Y, *Pandas for Everyone: Python Data Analysis*, Pearson, 2018.

(ii) Miller J.D. *Statistics for Data Science,* Packt Publishing, 2017.

GENERIC ELECTIVES (GE-2b): Data Analysis and Visualization using Spreadsheet

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		
GE2b **Data Analysis and Visualization using Spreadsheet**	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**Nil**

Learning Objectives

This course is designed to inculcate statistical thinking about data to the students who have studied Mathematics up to Class 10^{th} ONLY. It gently introduces the students to basic statistics, and builds gradually to cover advanced functionalities for data analysis in spreadsheets. The objective is to enhance the knowledge of statistics and enable students to make sense of data by analyzing and visualizing it using spreadsheets, interpreting the results and gaining insights.

Learning outcomes

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

- Analyze and visualize data using spreadsheets
- Apply basic and advanced level statistical functions in spreadsheets
- Gain practical, hands-on experience of data analysis using spreadsheet

SYLLABUS OF GE-2b

UNIT – I (09 Hours)

Introduction to Basic Statistics

Fundamentals of Data Analysis, Statistical foundations for Data Analysis, Types of data, Descriptive Statistics, Correlation and covariance, Linear Regression.

UNIT – II (15 Hours)

Data Handling

Spreadsheet concepts, managing worksheets, formatting cells, entering data, Handling operators in formula, Cell referencing and naming of cells and cell ranges, Sorting, Multilayer sorting, Data validation, Find and Replace, Paste special, Filter and advanced filter, Formatting as table, Pivot tables, Formulae vs functions, Cell formulae vs Array formulae.

Mathematical functions, Statistical functions, Logical functions, Date and Time functions, Lookup and reference: Hlookup, and Vlookup, Index and Match functions, Text functions.

What–if-analysis: Goal-seek, Data tables, Scenario manager.

UNIT – III (12 Hours)

Data Analysis

Explore a data model: its content, and its structure, using the Power Pivot add-in. Learning DAX formula language. Create calculated fields and calculated measure for each cell, filter context for calculation, and explore several advanced DAX functions.

Cube formulas to retrieve data from data model.

UNIT – IV (09 Hours)

Data Visualization

Different types of charts including Pivot charts: Column, Line, Pie, Bar, Scatter charts. Fine tuning of charts: Chart Elements, Chart Styles, Chart Filters, Box Plot.

Practical component (if any) – 30 Hours

1. In a meeting of a marketing department of an organization it has been decided that price of selling an item is fixed at Rs. 40. It was resolved to increases the selling of more items and getting the profit of Rs. 50000/-. Use Goal Seek of find out how many items you will have to sell to meet your profit figure.
2. Create worksheet related to crop production of various crops in Indian stats in last five years (wheat, rice, pulses, soya-bean, and cane-sugar etc).
    i) Make a bar chart
    ii) Make a pie chart
    iii) Make a box plot
3. Study and perform the various DAX functions to analyse the data.
4. Create workbook related to sales of Business Company having various product in last four quarters for 10 sales persons.
    i) Make a line graph to show the growth/decline in the sales
    ii) Show the graph of each sales person sales
    iii) Find the two sales persons done in last 2 quarters
    iv) Find the sales persons consistent in last four quarters
    v) Find the most popular product of the company and the current popular product of company.
5. Create a Pivot-table showing the Customer Names who placed orders with GSS during 2019-2022. For each customer, also show the total number of orders, Total Sales, and Total Profit. Add a Slicer or a Filter that can be used to show the information specifically for each Customer Segment. Use information from the Pivot- table to answer the following questions (Hint: Filter and sort the data in the Pivot- table to locate the answer):
    i) Which small business customer had the highest sales?
    ii) Which corporate customer placed the greatest number of orders in 2019-2022? How many orders were placed by the corporate customer?
    iii) Which consumer customer was the most profitable one?
    iv) What is the sales figure of the least profitable home office customer?
6. Consider the following worksheet: (enter 5 records)

FULL NAME	GRADE 1/2/3	BASIC SALARY	HRA	PF	GROSS	NET	VA	VA>HRA

HRA is calculated as follows:

Grade	HRA (% of basic)
1	40%
2	35%
3	30%

PF is 8% for all grades

VA is 15000, 10000, 7000 for Grades 1, 2 and 3.

Gross=Basic + HRA+VA

Net=Gross - PF

i) Find max, min and average salary of employees in respective Grade.
ii) Count no. of people where VA>HRA
iii) Find out most frequently occurring grade.
iv) Extract records where employee name starts with "A" has HRA>10000
v) Print Grade wise report of all employees with subtotals of net salary and also grand totals.
vi) Use subtotal command.
vii) Extract records where Grade is 1 or 2 and salary is between 10000 and 20000 both inclusive.

7. Create workbook related to sales of Business Company having various product in last ten quarters for 20 sales persons. Perform the following on workbook:
   i) Create and modify a Pivot-table
   ii) Apply Pivot-table styles and formatting
   iii) Filter a Pivot-table
   iv) Insert a slicer to filter a Pivot-table
   v) Create a Pivot Chart

8. Create a PivotTable showing Total Sales breakdown by Region, Product Category, and Product Sub-Category. Use information from the PivotTable to answer the following questions:
   i) What was the Total Sales figure included in this data set?
   ii) Which Product Category had the highest sales?

iii) Which Region had the lowest sales?
iv) What was the Total Sales of Appliances in Delhi?

9. You are required to prepare a payroll statement in the given format making maximum use of cell referencing facility:

Code	Name	Category	Is HRA to be Paid	Basic	DP	DA	HRA	TA	CCA	Gross
1			Y							
2			N							
	Total									

Required:

- Basic salary (Allow any Basic salary in the range of Rs.10000-35000)
- DP is 50% of Basic Salary.
- DA (as a Percentage of Basic + DP) is more than 35000 then 40% of basic else 30% of basic.
- HRA is to be paid @ 40% of (Basic plus DP) to those whom HRA payable is yes.
- TA is to be paid @ Rs. 800 PM if Basic Salary is Less than Rs.12000, otherwise the TA is Rs. 1000 PM)
- CCA is to be paid @ Rs. 300 PM if Basic Salary is less than Rs.12000/- otherwise the CCA is Rs. 500 PM)
- Gross salary is the sum of Salary and all other allowances
- Deduction: a) GPF 10% of (Basic +DP) subject to a minimum of Rs.2000/- b) IT 10% of Gross Salary
- Net salary is Gross salary minus total deductions.

10. Consider the following worksheet for APS 1st year students:

S.No.	Name	Physics	Chem	Bio	Maths	CS	Total	%	Grade

1									
2									
3									
4									
5									

The value of Grade is calculated as follows:

If % >=90	Grade A

If % >=80 & <90	Grade B
If % >=70 & <80	Grade C
If % >=60 & <70	Grade D

Otherwise, students will be declared fail.

i) Calculate Grade using if function
ii) Sort the data according to total marks
iii) Apply filter to display the marks of the students having more than 65% marks.
iv) Enter the S.No. of a student and find out the Grade of the student using VLOOKUP.
v) Extract all records where name
   a) Begins with “A”
   b) Contains “A”
   c) Ends with “A”

Essential/recommended readings

1. Gupta, S.P., *Elementary Statistical Methods*, Sultan Chand and Sons, New Delhi, 2017.

2. Goldmeier, J., *Advanced Excel Essentials*, Apress, 2014.
3. Slager, D., *Essential Excel 2016: A Step-by-Step Guide*, Apress, 2016.
4. Valerie M. Sue and Matthew T. Griffin, *Data Visualization and Presentation with Microsoft Office*, SAGE, 2016.
5. Schmuller, J., *Statistical Analysis with Excel for Dummies*, 4th edition., Wiley India Pvt Ltd., 2020.

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

DEPARTMENT OF STATISTICS

B. Sc. (H) Statistics

Category-I

DISCIPLINE SPECIFIC CORE COURSE-4: THEORY OF PROBABILITY 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		
Theory of probabilit distributions	4	3	0	1	Class XII pass with Mathematics	Descriptive Statistics, Probability Theory, Calculus

Learning Objectives

The learning objectives of this course are as follows:

- Acquaint students with requisite tools for problem-solving available in statistical methodology.
- Prepare students to handle two/three-dimensional data and familiarize them with different measures of association as well as regression.
- Introduction to various discrete and continuous distributions and their properties.

Learning Outcomes

The learning outcomes of this course are as follows:

- Understand the role of expectation and its usefulness. Get familiar with different kind of generating functions and their strength and weaknesses
- Handle problems based on two-dimensional random variables using Jacobians and bivariate transformations.
- Understand and exploit various measures of correlation and regression for problem-solving.
- Familiarize with the concept of partial and multiple correlation coefficients and their properties
- Get acquainted with various discrete and continuous distributions their properties and interrelations and solve problems based on them.

SYLLABUS OF DSC-4

Theory

UNIT I **(09 Hours)**

Expectation

Mathematical Expectation: Conditional expectations and its properties. Bivariate transformations with illustrations. Moments, moment generating function and its properties. Cumulants, cumulant generating function and its properties. Characteristic function and its properties. Inversion theorem for continuous random variables (without proof) along with applications.

UNIT II **(12 Hours)**

Expectation (contd.)

Some inequalities involving expectation - Cauchy Schwartz Inequality, Jenson's inequality.

Two-dimensional random variables: Joint probability mass function/ Joint probability density function, marginal and conditional probability mass function/ probability density function, independence of random variables, examples based on joint/marginal/conditional pmf/pdf.

Conditional expectation and variance, Jacobian of transformation, Bivariate transformation of random variables, and Examples based on bivariate transformation.

UNIT III **(09 Hours)**

Correlation and Regression

Properties of various measures of correlation and regression using expectation**,** Correlation Ratio, Intra-class correlation, Partial and multiple correlations – definition, Yule's notation, the plane of regression, properties of residuals, multiple and partial correlation coefficients and their properties (derivation based on three variables), the relationship between multiple, partial and total correlations and examples based on them.

UNIT IV **(15 Hours)**

Probability Distributions

Discrete probability distribution – Binomial, Poisson- measures of central tendency, dispersion, skewness and kurtosis, recurrence relations based on moments, moment generating function, cumulant generating function, characteristic function, additive property, fitting of distribution, and examples based on application.

Continuous Probability distribution - Normal - measures of central tendency, dispersion, skewness and kurtosis, recurrence relations based on moments, moment generating function, cumulant generating function, characteristic function, additive property fitting of distribution and examples based on application, Uniform distribution – moments, mgf, mean deviation and examples based on bivariate transformations.

PRACTICAL – 30 Hours

List of Practicals:

1. Practical based on regression lines and properties of regression coefficients.
2. Practical based on Correlation ratio.
3. Practical based on Intra-class correlation.
4. Practical based on multiple correlation coefficient.
5. Practical based on partial correlation coefficient.

6. Practical based on planes of regression.
7. Word problems based on application s of Binomial distribution.
8. Practical based on fitting of Binomial distribution (when parameters are given).
9. Practical based on fitting of Binomial distribution (when parameters are not given).
10. Practical based on calculation of area under the normal curve.
11. Practical based on calculation of ordinates given area under the normal curve.
12. Practical based on fitting of the normal curve when parameters are not given.
13. Practical based on use of normal approximation to the binomial distribution.

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

ESSENTIAL READINGS

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016). *An Outline of Statistical Theory,* Vol. I, The World Press, Kolkata.
- Gupta, S. C. and Kapoor, V. K. (2020). *Fundamentals of Mathematical Statistics*, 12th Edn., S. Chand and Sons. Delhi.
- Hogg, R.V., Tanis, E.A. and Rao, J.M. (2009). *Probability and Statistical Inference*, 7th Ed., Pearson Education, New Delhi.
- Miller, I. and Miller, M. (2006). *John E. Freund's Mathematical Statistics with Applications*, 8th Ed., Pearson Education, Asia.
- Mukhopadhyay, P. (2016). *Mathematical Statistics.* Books And Allied, India.

SUGGESTED READINGS

- Mood, A.M. Graybill, F.A. and Boes, D.C. (2007). *Introduction to the Theory of Statistics*, 3rd Ed., (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
- Rohatgi, V. K and Saleh M. E. (2015). *An Introduction to Probability and Statistics,* 3rd Edn. John Wiley & Sons, Inc., New Jersey.

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

DISCIPLINE SPECIFIC CORE COURSE-5: APPLIED STATISTICS 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		
Applied Statistics I	4	3	0	1	Class XII pass with Mathematics	Descriptive Statistics

Learning Objectives

The learning objectives of this course are as follows:

- This course will help students to know the applications of Statistics and learn and apply these concepts in real life situations.
- This course will give exposure to two applied fields of statistics viz. Vital Statistics and Index Numbers.
- They will be having hands on practice of working on the data related to above mentioned fields.
- This course will help them understand about the working of the Indian Official Statistical System.

Learning Outcomes:

The learning outcomes of this course are as follows:

- Understanding of the distinction between Vital Statistics and Demography.
- Knowledge of basic measures of Mortality, Fertility, and Population Growth.
- Ability to construct of Life Tables.
- Understanding of fundamental concepts of Index Numbers.
- Ability to construct Price and Quantity Index numbers, Consumer and Wholesale Price Index Numbers.
- Knowledge of Official Statistical System in India, Statistical offices at the Centre and States along with their functions.

SYLLABUS OF DSC-5

Theory

UNIT I **(18 Hours)**

Vital Statistics

Introduction, Sources of collecting vital statistics, Errors in census and registration data, Uses of Vital Statistics. Measurements of mortality: Crude death rate (CDR), Age specific death rate (ASDR), Standardized death rates and Infant mortality rate.

Life table: Assumptions, description and construction of Complete life table. Definition of Abridged life table.
Measurements of fertility: Crude birth rate (CBR), General fertility rate (GFR), Age specific fertility rate (ASFR), Total fertility rate (TFR).
Measurements of population growth: Crude rate of natural increase, Pearle's vital index, Gross reproduction rate (GRR) and Net reproduction rate (NRR).

UNIT 2 **(12 Hours)**

Index numbers

Introduction, Problems involved in the construction of index numbers, Constructions of index numbers of Prices and Quantities. Index numbers based on Average of Price Relatives, Criteria for a good Index numbers. Errors in the measurement of Price and Quantity Index Numbers, Consumer price index number, Concept of Wholesale price index number with interpretation. Uses and Limitation of Index numbers.

UNIT 3 **(15 Hours)**

Indian Official Statistics

Introduction, Present official statistical system in India, Statistical offices at the Centre, Statistical offices in the States, Methods of collection of official statistics on population, price (retail as well wholesale).

PRACTICAL -30 Hours

List of Practicals:

1. To calculate CDR and ASDR for a given set of data
2. To find Standardized death rate by Direct and Indirect method
3. To construct a complete life table
4. To fill in the missing entries in a life table
5. To calculate CBR and GFR for a given set of data
6. To calculate ASFR for a given set of data
7. To calculate TFR for a given set of data
8. To calculate Crude rate of Natural Increase and Pearle's Vital Index
9. To calculate GRR and NRR for a given set of data and compare them
10. To Construct price and quantity index numbers by Laspeyre's, Paasche's, Marshall-Edgeworth, Drobish -Bowley, Walsch and Fisher's Formula.
11. To test the goodness of an Index number using Time Reversible Test and Factor Reversible Test
12. To Construct price index numbers based on Average of Price Relatives
13. To Construct Chain base index numbers
14. Base shifting, Splicing and Deflating of Index Numbers
15. To construct Consumer price index number using Aggregate Expenditure method and Family Budget method and compare

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

ESSENTIAL READINGS:

- Croxton, Fredrick E, Cowden, Dudley J. and Klein, S. (1973): Applied General Statistics, 3rd edition, Prentice Hall of India Pvt. Ltd.

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th edition, World Press Pvt. Ltd.
- Gupta, S.C., and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4th edition (reprint 2010), Sultan Chand and Sons.
- Mukhopadhyay P. (2011): Applied Statistics, 2nd edition (revised reprint), Books and Allied Pvt. Ltd.

SUGGESTED READINGS

- Benjamin, B. (1968): Health and Vital Statistics. G. Allen and Unwin.
- Mudgett B.D. (1951): Index Numbers, John Wiley.
- Allen R.G.D. (1975): Index Numbers in Theory and Practice, Macmillan.
- Nagar A.L. & Das R. K. (1976): Basic Statistics.

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

DISCIPLINE-SPECIFIC CORE COURSE-6: ALGEBRA FOR 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		
Algebra For Statistics	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives

• Algebra serves as a building block that will enable students to learn more advanced techniques that will help them to solve problems more quickly and easily.

Learning Outcomes:

The learning outcomes of this course are as follows:

- Understanding the fundamental concepts of matrices and determinants
- Understanding of partitioning of matrices, Echelon form
- Solving Linear equations
- Knowledge of Vector spaces and Subspaces, Orthonormal Basis
- Identifying rank of a Matrix
- Computing generalized inverse, characteristic roots and vectors, quadratic forms

SYLLABUS OF DSC-6

Theory

UNIT I **(09 Hours)**

Algebra of matrices

A review related to triangular, symmetric, and skew-symmetric matrices, singular, and non-singular matrices, and their properties.

Idempotent matrices, Hermitian and skew Hermitian matrices, orthogonal matrices, Trace of a matrix, unitary, involutory and nilpotent matrices. Adjoint and inverse of a matrix and related properties. Partitioning of matrices and simple properties.

UNIT II **(12 Hours)**

Determinants

A review related to properties and applications of determinants for 3rd and higher orders. Alternant determinant, Circulant determinant, Jacobi's Theorem, the product of determinants. Use of determinants in solution to the system of linear equations, row reduction and echelon forms, the matrix equations AX=B, solution sets of linear equations, Applications of linear equations, inverse of a matrix.

UNIT III **(09 Hours)**

Vector spaces

Vector spaces, Subspaces, sum of subspaces, Span of a set, Linear dependence and independence, dimension and basis, Gram Schmidt Orthogonalization Process. Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum, and the product of two matrices.

UNIT IV **(15 Hours)**

Generalized Inverse

Generalized inverse (concept, properties with illustrations). Characteristic roots and characteristic vector, Properties of characteristic roots and characteristic vector, Cayley Hamilton theorem and application, Spectral Decomposition. Quadratic forms, Derivatives of linear functions, and quadratic forms. Linear orthogonal transformation and their diagonalization.

PRACTICAL – 30 Hours

List of Practicals:

1. Inverse of a matrix by method of partitioning.
2. Every non-singular square matrix can be expressed as product of elementary matrices.
3. Generalised Inverse of a matrix and Symmetric Generalised Inverse of a matrix.
4. Find XGX' for any matrix X of order nxk; k< n, where G is generalized inverse of $X'X$ and study its properties.
5. Construction of Idempotent matrix and study its properties.
6. Construction of Orthogonal matrix and study its properties.
7. Characteristic roots and characteristic vectors and its properties

8. Cayley Hamilton Theorem and application.
9. Quadratic Form:
   (a) Reducing Quadratic Form into canonical form and find rank, index and signature of the form.
   (b) Identify the nature of Quadratic Form.
10. Construction of an orthonormal basis vector using Gram Schmidt Orthogonalization process.

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

ESSENTIAL READINGS:

- Searle, S.R.: Matrix Algebra useful for Statistics, John Wiley & Sons, 1982.
- Krishnamurthy, V., Mainra, V.P. and Arora, J.L. (2015). An Introduction to Linear Algebra, East West Press Pvt. Ltd., New Delhi.
- Hadley, G.: Linear Algebra, Narosa Publishing House (Reprint), 2002.
- Gupta, S. C.: An Introduction to Matrices (Reprint), Sultan Chand & Sons, 2008.

SUGGESTED READINGS:

- Biswas, S. (1997). A Textbook of Matrix Algebra, New Age International.
- Singal, M.K. and Singal, Asha Rani: Algebra, R. Chand & Co., 2011.

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

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

Category-II

DISCIPLINE SPECIFIC CORE COURSE – 3: Statistical

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	4	3	0	1	Class XII pass with Mathematics	Descriptive Statistics

Course Objectives:

The learning objectives include:

- To know the difference between discrete and continuous random variables.
- To develop the thinking of students so that they can use the concepts of statistical probability distribution in real life.
- To understand the concept of random variables, probability distributions and expectation

Course Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of random variables.
- Basic concepts of discrete & continuous random variables.
- Distinguish between Moments generating functions & Cumulant generating functions
- Concept of joint, marginal and conditional probability distribution for two dimensional random variables and their independence.
- Discrete probability distributions with their properties.
- Continuous probability distributions with their properties.

SYLLABUS OF DSC

Theory

Unit – 1 **(15 hours)**

Random Variables

Random variables: Discrete and continuous random variables, pmf, pdf and cdf, illustrations of random variables and its properties, expectation of random variable and its properties. Variance, covariance and their properties with illustrations. Moments and cumulants, moment generating function with properties, cumulants generating function and characteristic function.

Unit – 2 **(08 hours)**

Bivariate Probability Distribution

Bivariate probability distributions, marginal and conditional distributions, independence of variates (only general idea to be given). Transformation in univariate and bivariate distributions.

Unit – 3 **(10 hours)**

Discrete Probability Distributions

Discrete probability distributions – Binomial, Poisson- measures of central tendency, dispersion, skewness and kurtosis, recurrence relations based on moments, moment generating function, cumulant generating function, characteristic function, additive property, fitting of distribution and examples.

Unit – 4 **(12 hours)**

Continuous Probability Distributions

Continuous Probability distribution - Normal - measures of central tendency, dispersion, skewness and kurtosis, recurrence relations based on moments, moment generating function, cumulant generating function, characteristic function, additive property and examples. Exponential distribution – moment generating function and lack of memory. Gamma distribution – moment generating function, cumulant generating function and additive property.

Practicals

List of Practicals: **(30 hours)**

(Practical to be performed on computer using Microsoft Excel/Electronic Spreadsheet/SPSS/Any Statistical Package

1. Problems based on expectations, variance and co-variances.
2. Fitting of binomial distributions for n and p = q = ½ and for n and p given.
3. Fitting of binomial distributions computing mean and variance.

4. Fitting of Poisson distributions for give n and λ and after estimating mean.
5. Fitting of suitable distribution.
6. Application problems based on Binomial distribution.
7. Application problems based on Poisson distribution.
8. Problems based on the Area property of Normal distribution.
9. Application problems based on Normal distribution.
10. Problems based on bivariate probability distributions.

Essential Readings

1. Goon, M., Gupta, M.K. and Dasgupta, B. (2003). *An outline of Statistical Theory*, Vol. I, 4th Ed., World Press, Kolkata.
2. Gupta, S.C. and Kapoor, V.K. (2020). *Fundamentals of Mathematical Statistics*, 12th Ed., Sultan Chand and Sons.
3. Hogg, R. V., McKean, J., and Craig, A. T. (2005). *Introduction to mathematical statistics*. Pearson Education.
4. Rohtagi, V.K. and Saleh, A.K. Md. E. (2009). *An Introduction to Probability and Statistics*, 2nd Ed., John Wiley and Sons.

Suggestive Readings

1. Ross, S.A. (2007). *Introduction to Probability Models*, 9 Ed., Academic Press
2. Mood, A.M., Graybill, F.A. and Boss, D.C. (2007). *Introduction to the Theory of Statistics*, 3rd Ed., Tata McGraw Hill Publication.

DISCIPLINE SPECIFIC CORE COURSE – 4: APPLICATIONS IN 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		
Applications i Statistics	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

- Acquaint students with the current official statistical system in India
- Familiarize students with important concepts of Demand Analysis
- Introduction to Utility and Production functions.

Learning Outcomes:

After taking this paper, the student should be able to:

- Understand the current and prevailing official statistical system in India, role of MoSPI, CSO, NSSO, and their important publication
- Understand the laws of demand and supply, Price and Income elasticity of demand.
- Differentiate between Partial and Cross Elasticities of Demand, Engel's law, Pareto's law, and different curves of concentration.
- Understand theory of utility function, Utility Curve, Marginal rate of substitution, Budget line, and Construction of Utility Curve.

SYLLABUS OF DSC

Theory

Unit I **(12 Hours)**

Indian Official Statistics

Present official statistical system in India, Methods of collection of official statistics and their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications.

Unit II **(12 Hours)**

Demand Analysis

Concept of differentiation and partial differential.

Introduction: Demand and Supply and its laws, Price Elasticity of Demand, Income elasticity of demand, Nature of commodities, Partial and Cross Elasticities of Demand, Types of data required for its estimation, computation of demand function from given price elasticity of demand, Engel's law and Engel Curves, Pareto's law of income distribution, Curves of concentration.

Unit III **(12 Hours)**

Utility Function

Introduction: Theory of Utility, Statistical decision making under Utilities, general definition of utility function, advantages and disadvantage of Utility function, Utility Curve, Basic axioms of Utility, example of utility function, Indifference curves and their properties, Marginal rate of substitution, Budget line, constrained utility maximization, Construction of Utility Curve.

Unit IV **(09 Hours)**

Production Function

Production function, Marginal productivity, Average productivity, Degree of production function, Linear homogeneous production function, Euler's theorem, Returns to scales, Isoquants, Isocost curves, Equilibrium of the firm, Marginal rate of technical substitution, Elasticity of substitution, Constant elasticity of substitution.

PRACTICAL - 30 Hours

List of Practical

1. Fitting of demand curve.
2. Calculate income elasticity of demand from given data.
3. Calculation of price elasticity of demand from the given data.
4. Estimation of constant demand function.
5. To fit Engel's curve and draw them.
6. Comparison of inequality in distribution of expenditure.
7. Fitting of Pareto distribution to given data.
8. Computation and plotting of Lorenz Curve and computation of concentration ratio.

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

ESSENTIAL READINGS:

- Fundamentals of Statistics, Vol.2, Goon, A. M., Gupta, M. K. and Dasgupta, B. (2001). World Press.
- Business Mathematics with Applications, S.R. Arora and Dinesh Khattar, S.Chand & Company Ltd.
- Applied Statistics, Parimal Mukhopadhyay (2011), Books and Allied (P) Ltd.
- Business Mathematics Theory and Applications, V.K. Kapoor (2012), Sultan Chand & Sons.

SUGGESTED READINGS:

- Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.
- mospi.nic.in/nscr/iss.html.
- Business Mathematics with applications in Business and Economics, R.S. Soni, Pitambar Publishing Company (P) 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 – 2: Statistical

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	4	3	0	1	Class XII pass with Mathematics	Descriptive Statistics

Course Objectives:

The learning objectives include:

- To know the difference between discrete and continuous random variables.
- To develop the thinking of students so that they can use the concepts of statistical probability distribution in real life.
- To understand the concept of random variables, probability distributions and expectation

Course Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of random variables.
- Basic concepts of discrete & continuous random variables.
- Distinguish between Moments generating functions & Cumulant generating functions
- Concept of joint, marginal and conditional probability distribution for two dimensional random variables and their independence.
- Discrete probability distributions with their properties.
- Continuous probability distributions with their properties.

SYLLABUS OF DSC

Theory

Unit – 1 **(15 hours)**

Random Variables

Random variables: Discrete and continuous random variables, pmf, pdf and cdf, illustrations of random variables and its properties, expectation of random variable and its properties. Variance, covariance and their properties with illustrations. Moments and cumulants, moment generating function with properties, cumulants generating function and characteristic function.

Unit – 2 **(8 hours)**

Bivariate Probability Distribution

Bivariate probability distributions, marginal and conditional distributions, independence of variates (only general idea to be given). Transformation in univariate and bivariate distributions.

Unit – 3 **(10 hours)**

Discrete Probability Distributions

Discrete probability distributions – Binomial, Poisson- measures of central tendency, dispersion, skewness and kurtosis, recurrence relations based on moments, moment generating function, cumulant generating function, characteristic function, additive property, fitting of distribution and examples.

Unit – 4 **(12 hours)**

Continuous Probability Distributions

Continuous Probability distribution - Normal - measures of central tendency, dispersion, skewness and kurtosis, recurrence relations based on moments, moment generating function, cumulant generating function, characteristic function, additive property and examples. Exponential distribution – moment generating function and lack of memory. Gamma distribution – moment generating function, cumulant generating function and additive property.

Practicals

List of Practicals: **(30 hours)**

(Practical to be performed on computer using Microsoft Excel/Electronic Spreadsheet/SPSS/Any Statistical Package

1. Problems based on expectations, variance and co-variances.
2. Fitting of binomial distributions for n and p = q = ½ and for n and p given.
3. Fitting of binomial distributions computing mean and variance.
4. Fitting of Poisson distributions for give n and λ and after estimating mean.
5. Fitting of suitable distribution.
6. Application problems based on Binomial distribution.
7. Application problems based on Poisson distribution.

8. Problems based on the Area property of Normal distribution.
9. Application problems based on Normal distribution.
10. Problems based on bivariate probability distributions.

Essential Readings

1. Goon, M., Gupta, M.K. and Dasgupta, B. (2003). *An outline of Statistical Theory*, Vol. I, 4th Ed., World Press, Kolkata.
2. Gupta, S.C. and Kapoor, V.K. (2020). *Fundamentals of Mathematical Statistics*, 12th Ed., Sultan Chand and Sons.
3. Hogg, R. V., McKean, J., and Craig, A. T. (2005). *Introduction to mathematical statistics*. Pearson Education.
4. Rohtagi, V.K. and Saleh, A.K. Md. E. (2009). *An Introduction to Probability and Statistics*, 2nd Ed., John Wiley and Sons.

Suggestive Readings

1. Ross, S.A. (2007). *Introduction to Probability Models*, 9 Ed., Academic Press
2. Mood, A.M., Graybill, F.A. and Boss, D.C. (2007). *Introduction to the Theory of Statistics*, 3rd Ed., Tata McGraw Hill Publication.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY DEPARTMENT OF STATISTICS
CATEGORY-IV

GENERIC ELECTIVES : INTRODUCTORY PROBABILITY

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		
Introductory Probability	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives :

- Acquaint students with the mathematical foundation of probability.
- familiarize students with important tools for statistical analyses at introductory level.
- Introduction to some common discrete and continuous distributions and their properties.

Learning Outcomes:

After taking this paper, the student should be able to:

- Understand the meaning of probability and probabilistic experiment. Various approaches to probability theory and in particular the axiomatic approach. Laws of probability, conditional probability, conditioning, and reduced sample space, compute joint and conditional probabilities. Bayes' rule and applications.
- Understand the concept of a random variable, expectation and its properties, Compute variance and covariance in terms of expectation. Moment generating function and its properties.
- Get familiar with some standard discrete and continuous distribution and the usefulness of Central limit Theorem in daily life.

SYLLABUS OF GE

Theory

UNIT-I **(12 Hours)**

Probability

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic. Conditional

Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.

UNIT II **(18 Hours)**

Random Variables

Random Variables: Discrete and continuous random variables, pmf, pdf, cdf. Illustrations of random variables and its properties. Expectation, variance, moments and moment generating function.

UNIT III **(15 Hours)**

Probability Distributions

Standard probability distributions: Binomial, Poisson, Geometric, Negative Binomial, Hypergeometric, Uniform, Normal, Exponential, Beta, Gamma. De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T.) (Only Statements)

PRACTICAL - 30 Hours

List of Practical:

1. Application problems based on addition law of probability.
2. Application problems based on conditional probability.
3. Application problems based on Bayes law.
4. Application problems based on Expectation of random variable.
5. Computing MGF and how it helps in finding moments.
6. Computing cdf for discrete and continuous random variables drawing its graph.
7. Fitting of binomial distributions for n and p = q = ½
8. Fitting of binomial distributions for n and p given.
9. Fitting of binomial distributions computing mean and variance.
10. Fitting of Poisson distributions for given value of lambda.
11. Fitting of Poisson distributions after computing mean.
12. Application problems based on binomial distribution.
13. Application problems based on Poisson distribution.
14. Problems based on area property of normal distribution.
15. To find the ordinate for a given area for normal distribution.
16. Application based problems using normal distribution.
17. Fitting of normal distribution when parameters are given.
18. Fitting of normal distribution when parameters are not given.
19. Computing probabilities using Microsoft Excel functions binomdist(), poisson(), normsdist(), normsinv(), normdist(), and norminv().
20. Computing Binomial probabilities for large n and small p using Microsoft Excel functions binomdist() and poisson().
21. Computing Binomial probabilities for large n and p $\in$ (0.4, 0.6) using Microsoft Excel functions binomdist() and normdist().

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

SUGGESTED READINGS:

1. Hogg, R.V., Tanis, E.A. and Rao, J.M. (2009). Probability and Statistical Inference, 7th Ed, Pearson Education, New Delhi.
2. Miller, I. and Miller, M. John E. Freund (2006). Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia.
3. Myer, P.L. (1970). Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.

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

GENERIC ELECTIVES : APPLICATIONS IN 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		
Applications in Statistics-II	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

- Acquaint students with the current official statistical system in India
- Familiarize students with important concepts of Demand Analysis
- Introduction to Utility and Production functions.

Learning Outcomes:

After taking this paper, the student should be able to:

- Understand the current and prevailing official statistical system in India, role of MoSPI, CSO, NSSO, and their important publication
- Understand the laws of demand and supply, Price and Income elasticity of demand.
- Differentiate between Partial and Cross Elasticities of Demand, Engel's law, Pareto's law, and different curves of concentration.
- Understand theory of utility function, Utility Curve, Marginal rate of substitution, Budget line, and Construction of Utility Curve.

SYLLABUS OF GE

Theory

Unit I **(09 Hours)**

Indian Official Statistics

Present official statistical system in India, Methods of collection of official statistics and their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications.

Unit II **(12 Hours)**

Demand Analysis

Concept of differentiation and partial differential.

Introduction: Demand and Supply and its laws, Price Elasticity of Demand, Income elasticity of demand, Nature of commodities, Partial and Cross Elasticities of Demand, Types of data required for its estimation, computation of demand function from given price elasticity of demand, Engel's law and Engel Curves, Pareto's law of income distribution, Curves of concentration.

Unit III **(12 Hours)**

Utility Function

Introduction: Theory of Utility, Statistical decision making under Utilities, general definition of utility function, advantages and disadvantage of Utility function, Utility Curve, Basic axioms of Utility, example of utility function, Indifference curves and their properties, Marginal rate of substitution, Budget line, constrained utility maximization, Construction of Utility Curve.

Unit IV **(12 Hours)**

Production Function

Production function, Marginal productivity, Average productivity, Degree of production function, Linear homogeneous production function, Euler's theorem, Returns to scales, Isoquants, Isocost curves, Equilibrium of the firm, Marginal rate of technical substitution, Elasticity of substitution, Constant elasticity of substitution.

PRACTICAL - 30 Hours

List of Practical

1. Fitting of demand curve.
2. Calculate income elasticity of demand from given data.
3. Calculation of price elasticity of demand from the given data.
4. Estimation of constant demand function.
5. To fit Engel's curve and draw them.
6. Comparison of inequality in distribution of expenditure.
7. Fitting of Pareto distribution to given data.
8. Computation and plotting of Lorenz Curve and computation of concentration ratio.

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

ESSENTIAL READINGS:

- Fundamentals of Statistics, Vol.2, Goon, A. M., Gupta, M. K. and Dasgupta, B. (2001). World Press.
- Business Mathematics with Applications, S.R. Arora and Dinesh Khattar, S.Chand & Company Ltd.
- Applied Statistics, Parimal Mukhopadhyay (2011), Books and Allied (P) Ltd.
- Business Mathematics Theory and Applications, V.K. Kapoor (2012), Sultan Chand & Sons.

SUGGESTED READINGS:

- Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.
- mospi.nic.in/nscr/iss.html.
- Business Mathematics with applications in Business and Economics, R.S. Soni, Pitambar Publishing Company (P) Ltd.

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

REGISTRAR