

UNIVERSITY OF DELHI

CNC-II/093/1(22)/2022-23/216

Dated: 10.10.2022

**NOTIFICATION**

Sub: Amendment to Ordinance V

[E.C Resolution No. 18-1/ (18-1-4) dated 18.08.2022]

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-I 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**

**B.SC. (H) MATHEMATICS**

**Category-I**

**DISCIPLINE SPECIFIC CORE COURSE – 1: 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		
Algebra	4	3	1	0	Class XII pass with Mathematics	Nil

**Learning Objectives**

The primary objective of this course is to introduce:

- The basic tools of theory of equations, number theory, and group theory.
- Symmetry group of a plane figure, basic concepts of cyclic groups.
- Classification of subgroups of cyclic groups.

**Learning Outcomes:**

This course will enable the students to:

- Determine number of positive/negative real roots of a real polynomial.

- Solve cubic and quartic polynomial equations with special condition on roots and in general.
- Employ De-Moivre's theorem in a number of applications to solve numerical problems.
- Use modular arithmetic and basic properties of congruences.
- Recognize the algebraic structure, namely groups, and classify subgroups of cyclic groups.

## SYLLABUS OF DSC-1

### Theory

#### Unit – 1 (24 hours)

##### Theory of Equations and Complex Numbers

General properties of polynomials and equations, Fundamental theorem of algebra, Relations between the roots and the coefficients, Upper bounds for the real roots; Theorems on imaginary, integral and rational roots; Newton's method for integral roots, Descartes' rule of signs; De-Moivre's theorem for integer and rational indices and their applications, The  $n$ th roots of unity, Cardan's solution of the cubic, Descartes' solution of the quartic equation.

#### Unit – 2 (16 hours)

##### Basic Number Theory

Division algorithm in  $\mathbb{Z}$ , Divisibility and the Euclidean algorithm, Fundamental theorem of arithmetic, Modular arithmetic and basic properties of congruences.

#### Unit – 3 (20 hours)

##### Basics of Group Theory

Groups, Basic properties, Symmetries of a square, Dihedral group, Order of a group, Order of an element, Subgroups, Center of a group, Centralizer of an element, Cyclic groups and properties, Generators of a cyclic group, Classification of subgroups of cyclic groups.

### Practical component (if any) - NIL

### Essential Readings

1. Andreescu, Titu & Andrica, D. (2014). Complex numbers from A to...Z. (2nd ed.). Birkhäuser.
2. Dickson, Leonard Eugene (2009). First Course in the Theory of Equations. John Wiley & Sons, Inc. The Project Gutenberg eBook: <http://www.gutenberg.org/ebooks/29785>
3. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint 2021.
4. Goodaire, Edgar G., & Parmenter, Michael M. (2006). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint 2018.

### Suggestive Readings

- Burnside, W.S., & Panton, A.W. (1979), The Theory of Equations, Vol. 1. Eleventh

Edition, (Fourth Indian Reprint. S. Chand & Co. New Delhi), Dover Publications, Inc.

- Burton, David M. (2011). Elementary Number Theory (7th ed.). McGraw-Hill Education Pvt. Ltd. Indian Reprint.
- Rotman, Joseph J. (1995). An Introduction to The Theory of Groups (4th ed.). Springer-Verlag, New York.

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

**DISCIPLINE SPECIFIC CORE COURSE – 2:  
ELEMENTARY REAL ANALYSIS**

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

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

**Learning Objectives**

The course will develop a deep and rigorous understanding of:

- Real line  $\mathbb{R}$  with algebraic.
- Order and completeness properties to prove the results about convergence and divergence of sequences and series of real numbers.

**Learning Outcomes**

This course will enable the students to:

- Understand the fundamental properties of the real numbers, including completeness and Archimedean, and density property of rational numbers in  $\mathbb{R}$ .
- Learn to define sequences in terms of functions from  $\mathbb{N}$  to a subset of  $\mathbb{R}$  and find the limit.
- Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate the limit superior and limit inferior of a bounded sequence.
- Apply limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

**SYLLABUS OF DSC - 2**

**Theory**

**Unit – 1**

**(16 hours)**

## **Real Number System**

Algebraic and order properties of  $\mathbb{R}$ , Absolute value of a real number, Bounded above and bounded below sets, Supremum and infimum of a non-empty subset of  $\mathbb{R}$ , The completeness property of  $\mathbb{R}$ , Archimedean property, Density of rational numbers in  $\mathbb{R}$ .

## **Unit – 2**

**(24 hours)**

### **Sequences**

Sequences and their limits, Convergent sequence, Limit theorems, Monotone sequences, Monotone convergence theorem, Subsequences, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior for bounded sequence, Cauchy sequence, Cauchy's convergence criterion.

## **Unit – 3**

**(20 hours)**

### **Infinite Series**

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence, Tests for convergence of positive term series, Integral test, Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's nth root test, Raabe's test, Alternating series, Leibniz test, Absolute and conditional convergence.

**Practical component (if any) – NIL**

### **Essential Readings**

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

### **Suggestive Readings**

- Aliprantis C. D., & Burkinshaw, O. (1998). Principles of Real Analysis (3rd ed.). Academic Press.
- Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian reprint.
- Thomson, B. S., Bruckner, A. M., & Bruckner, J. B. (2001). Elementary Real Analysis. Prentice Hall.

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

## DISCIPLINE SPECIFIC CORE COURSE – 3: PROBABILITY AND STATISTICS

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

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

#### Learning Objectives

The Learning Objectives of this course are as follows:

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

#### Learning Outcomes

This course will enable the students to:

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

### SYLLABUS OF DSC – 3

#### Theory

##### Unit – 1

(15 hours)

##### **Descriptive Statistics, Probability, and Discrete Probability Distributions**

Descriptive statistics: Populations, Samples, Stem-and-leaf displays, Dotplots, Histograms, Qualitative data, Measures of location, Measures of variability, Boxplots; Sample spaces and events, Probability axioms and properties, Conditional probability, Bayes' theorem and independent events; Discrete random variables and probability

distributions, Expected values; Probability distributions: Binomial, geometric, hypergeometric, negative binomial, Poisson, and Poisson distribution as a limit.

## **Unit – 2 (15 hours)**

### **Continuous Probability Distributions**

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

## **Unit – 3 (15 hours)**

### **Central Limit Theorem and Regression Analysis**

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

### **Practical (30 hours)**

Software labs using Microsoft Excel or any other spreadsheet.

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

### **Essential Reading**

1. Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences (9th ed.). Cengage Learning India Private Limited. Delhi. Indian Reprint 2020.

### **Suggestive Reading**

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

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

## B.Sc. (Prog.) with Mathematics as Major

### Category II

#### **DISCIPLINE SPECIFIC CORE COURSE – 1: ELEMENTS OF DISCRETE**

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

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

#### **Learning Objectives**

Students are introducing to:

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

#### **Learning outcomes**

This course will enable the students to:

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

#### **SYLLABUS OF DSC - 1**

##### **Theory**

##### **Unit – 1**

**(24 hours)**

##### **Sets, Relations and Functions**

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

**Unit – 2****(16 hours)****Lattices**

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

**Unit – 3****(20 hours)****Boolean Algebra and Switching Circuits**

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

**Practical component (if any) – NIL**

**Essential Readings**

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

**Suggestive Reading**

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

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

**DISCIPLINE SPECIFIC CORE COURSE – 2: TOPICS IN 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		
Topics in Calculus	4	3	1	0	Class XII pass with Mathematics	Nil

**Learning Objectives**

The primary objective of this course is to:

- Introduce the basic tools of calculus which are helpful in understanding their applications



in many real-world problems.

- Understand/create various mathematical models in everyday life.

### Learning Outcomes

This course will enable the students to:

- Understand continuity and differentiability in terms of limits and graphs of certain functions.
- Describe asymptotic behaviour in terms of limits involving infinity.
- Use of derivatives to explore the behaviour of a given function locating and classify its extrema and graphing the function.
- Apply the concepts of asymptotes, and inflexion points in tracing of cartesian curves.
- Compute the reduction formulae of standard transcendental functions with applications.

## SYLLABUS OF DSC - 2

### Theory

#### Unit – 1 (20 hours)

##### Limits, Continuity and Differentiability

Limit of a function,  $\varepsilon$ - $\delta$  definition of a limit, Infinite limits, Continuity and types of discontinuities; Differentiability of a function, Successive differentiation: Calculation of the  $n$ th derivatives, Leibnitz theorem; Partial differentiation, Euler's theorem on homogeneous functions.

#### Unit – 2 (20 hours)

##### Mean Value Theorems and its Applications

Rolle's theorem, Mean value theorems and applications to monotonic functions and inequalities; Taylor's theorem, Taylor's series, Maclaurin's series expansions of  $e^x$ ,  $\sin x$ ,  $\cos x$ ,  $\log(1+x)$  and  $(1+x)^m$ ; Indeterminate forms.

#### Unit – 3 (20 hours)

##### Tracing of Curves and Reduction Formulae

Asymptotes (parallel to axes and oblique), Concavity and inflexion points, Singular points, Tangents at the origin and nature of singular points, Curve tracing (cartesian and polar equations). Reduction formulae for  $\int \sin^n x dx$ ,  $\int \cos^n x dx$ , and  $\int \sin^m x \cos^n x dx$  and their applications.

### Practical component (if any) – NIL

### Essential Readings

- Prasad, Gorakh (2016). Differential Calculus (19th ed.). Pothishala Pvt. Ltd. Allahabad.
- Prasad, Gorakh (2015). Integral Calculus. Pothishala Pvt. Ltd. Allahabad.

### Suggestive Readings

- Apostol, T. M. (2007). Calculus: One-Variable Calculus with An Introduction to Linear Algebra (2nd ed.). Vol. 1. Wiley India Pvt. Ltd.
- Ross, Kenneth. A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian reprint.

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

## B.Sc. (Prog.) with Mathematics as Minor

### Category III

#### DISCIPLINE SPECIFIC CORE COURSE: TOPICS IN 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		
Topics in Calculus	4	3	1	0	Class XII pass with Mathematics	Nil

#### Learning Objectives

The primary objective of this course is to:

- Introduce the basic tools of calculus which are helpful in understanding their applications in many real-world problems.
- Understand/create various mathematical models in everyday life.

#### Learning outcomes

This course will enable the students to:

- Understand continuity and differentiability in terms of limits and graphs of certain functions.
- Describe asymptotic behaviour in terms of limits involving infinity.
- Use of derivatives to explore the behaviour of a given function locating and classify its extrema and graphing the function.
- Apply the concepts of asymptotes, and inflexion points in tracing of cartesian curves.
- Compute the reduction formulae of standard transcendental functions with applications.

#### SYLLABUS OF DSC

##### Theory

##### Unit – 1

(20 hours)

##### Limits, Continuity and Differentiability

Limit of a function,  $\varepsilon-\delta$  definition of a limit, Infinite limits, Continuity and types of discontinuities; Differentiability of a function, Successive differentiation: Calculation of the  $n$ th derivatives, Leibnitz theorem; Partial differentiation, Euler's theorem on homogeneous functions.

**Unit – 2****(20 hours)****Mean Value Theorems and its Applications**

Rolle's theorem, Mean value theorems and applications to monotonic functions and inequalities; Taylor's theorem, Taylor's series, Maclaurin's series expansions of

$e^x$ ,  $\sin x$ ,  $\cos x$ ,  $\log(1+x)$  and  $(1+x)^m$ ; Indeterminate forms.

**Unit – 3****(20 hours)****Tracing of Curves and Reduction Formulae**

Asymptotes (parallel to axes and oblique), Concavity and inflexion points, Singular points, Tangents at the origin and nature of singular points, Curve tracing (cartesian and polar equations). Reduction formulae for  $\int \sin^n x dx$ ,  $\int \cos^n x dx$ , and  $\int \sin^m x \cos^n x dx$  and their applications.

**Practical component (if any) – NIL****Essential Readings**

- Prasad, Gorakh (2016). Differential Calculus (19th ed.). Pothishala Pvt. Ltd. Allahabad.
- Prasad, Gorakh (2015). Integral Calculus. Pothishala Pvt. Ltd. Allahabad.

**Suggestive Readings**

- Apostol, T. M. (2007). Calculus: One-Variable Calculus with An Introduction to Linear Algebra (2nd ed.). Vol. 1. Wiley India Pvt. Ltd.
- Ross, Kenneth. A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian reprint.

**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 MATHEMATICS

## CATEGORY-IV

### GENERIC ELECTIVES: FUNDAMENTALS OF 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		
Fundamentals of Calculus	4	3	1	0	Class XII pass with Mathematics	NIL

#### Learning Objectives

The Learning Objectives of this course is as follows:

- Understand the quantitative change in the behaviour of the variables and apply them on the problems related to the environment.

#### Learning Outcomes

Upon completion of this course, students will be able to:

- Understand continuity and differentiability in terms of limits.
- Describe asymptotic behavior in terms of limits involving infinity.
- Understand the importance of mean value theorems and its applications.
- Learn about Maclaurin's series expansion of elementary functions.
- Use derivatives to explore the behavior of a given function, locating and classifying its extrema, and graphing the polynomial and rational functions.

#### SYLLABUS OF GE

##### Theory

##### Unit – 1

(20 hours)

##### Continuity and Differentiability of Functions

Limits and continuity, Types of discontinuities; Differentiability of functions; Successive differentiation: Calculation of the nth derivatives, Leibnitz theorem; Partial differentiation, Euler's theorem on homogeneous functions.

**Unit – 2** (20 hours)**Mean Value Theorems and its Applications**

Rolle's theorem, Mean value theorems and applications to monotonic functions and inequalities; Expansion of functions: Taylor's theorem, Taylor's series, Maclaurin's series expansion of  $e^x$ ,  $\sin x$ ,  $\cos x$ ,  $\log(1+x)$  and  $(1+x)^m$ ; Indeterminate forms.

**Unit – 3** (20 hours)**Tracing of Curves**

Concavity and inflexion points, Asymptotes (parallel to axes and oblique), Relative extrema, Tracing graphs of polynomial functions, rational functions, and polar equations.

**Practical component (if any) – NIL****Essential Readings**

- Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). Calculus (10th ed.). Wiley India Pvt. Ltd. New Delhi. International Student Version. Indian Reprint 2016.
- Prasad, Gorakh (2016). Differential Calculus (19th ed.). Pothishala Pvt. Ltd. Allahabad.

**Suggestive Reading**

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

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

**GENERIC ELECTIVES: THEORY OF EQUATIONS AND SYMMETRIES****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 Equations and Symmetries	4	3	1	0	Class XII pass with Mathematics	NIL

**Learning Objectives**

The goal of this course is to acquaint students with certain ideas about:

- Integral roots, rational roots, an upper bound on number of positive or negative roots of a polynomial.

- Finding roots of cubic and quartic equations in special cases using elementary symmetric functions.
- Using Cardon's and Descartes' methods, respectively.

### Learning outcomes

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

- Understand the nature of the roots of polynomial equations and their symmetries.
- Solve cubic and quartic polynomial equations with special condition on roots and in general.
- Find symmetric functions in terms of the elementary symmetric polynomials.

## SYLLABUS OF GE

### Theory

#### Unit - 1 (24 hours)

##### Polynomial Equations and Properties

General properties of polynomials and equations; Fundamental theorem of algebra and its consequences; Theorems on imaginary, integral and rational roots; Descartes' rule of signs for positive and negative roots; Relations between the roots and coefficients of equations, Applications to solution of equations when an additional relation among the roots is given; De Moivre's theorem for rational indices, the  $n$ th roots of unity and symmetries of the solutions.

#### Unit - 2 (16 hours)

##### Cubic and Biquadratic (Quartic) Equations

Transformation of equations (multiplication, reciprocal, increase/diminish in the roots by a given quantity), Removal of terms; Cardon's method of solving cubic and Descartes' method of solving biquadratic equations.

#### Unit - 3 (20 hours)

##### Symmetric Functions

Elementary symmetric functions and symmetric functions of the roots of an equation; Newton's theorem on sums of the like powers of the roots; Computation of symmetric functions such as  $\sum \alpha^2 \beta$ ,  $\sum \alpha^2 \beta^2$ ,  $\sum \alpha^2 \beta \gamma$ ,  $\sum \frac{1}{\alpha^2 \beta \gamma}$ ,  $\sum \alpha^3$ ,  $\sum (\alpha^2 \beta - \alpha \beta^2)$ ,  $\sum \frac{\alpha^2 + \beta \gamma}{\beta + \gamma}$  ... of polynomial equations; Transformation of equations by symmetric functions and in general.

### Practical component (if any) – NIL

### Essential Readings

- Burnside, W.S., & Panton, A.W. (1979). The Theory of Equations (11th ed.). Vol. 1.

Dover Publications, Inc. (4th Indian reprint. S. Chand & Co. New Delhi).

- Dickson, Leonard Eugene (2009). First Course in the Theory of Equations. John Wiley & Sons, Inc. The Project Gutenberg eBook: <http://www.gutenberg.org/ebooks/29785>

### **Suggestive Reading**

- Prasad, Chandrika (2017). Text Book of Algebra and Theory of Equations. Pothishala Pvt Ltd.

**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 – 1: DESCRIPTIVE 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		
Descriptive Statistics	4	3	0	1	Class XII pass with Mathematics	Nil

#### **Learning Objectives**

The Learning Objectives of this course are as follows:

- To tabulate statistical information given in descriptive form and to use graphical techniques to interpret
- To understand various measures of central tendency, dispersion, skewness and kurtosis. Moments and its properties.
- Familiarize with quantitative and qualitative data and available statistical tools to analyse them.
- Finding linear correlation between two variates using different measures and studying their properties. Least square method of fitting of curves, regression lines and their elementary properties.

#### **Learning Outcomes:**

The Learning Outcomes of this course are as follows:

- Understand concepts of sample vs. population and get acquainted with different types of data /scales. Distinguish between primary and secondary data. Tabulate and plot frequency distribution. Deals with numerical and graphical ways to describe and display data using histograms, stem and leaf plot and box plots.
- Calculate measures of central locations like mean, geometric mean, harmonic mean, median and mode and explain their properties
- Calculate measures of the spread: variance, standard deviation, range and inter-quartile range and explain their properties.
- Understand the meaning of probability and probabilistic experiment. Familiarize with the four approaches to probability theory and particularly, the axiomatic approach and use and manipulate the four axioms of probability comfortably to derive the results of other set

operations

- Understand and exploit Addition and Multiplicative laws of probability
- understand the meaning of conditional probability, conditioning, and reduced sample space, compute joint and conditional probabilities. independence, total probability, Bayes' rule and applications.
- Understand the concept of a random variable, differentiate between independent and uncorrelated random variables, distinguish between discrete, continuous, random variables and be able to represent them using probability mass, probability density, and cumulative distribution functions, Univariate transformation and its application.
- Understand expectation and its properties, Compute variance and covariance in terms of expectation. Solve problems based on expectation and its properties.

## **SYLLABUS OF DSC-1**

### **Theory**

#### **Unit – 1**

**(09 hours)**

##### **Data Visualization**

Statistical Methods: Definition and scope of Statistics, concepts of statistical population and sample. Types of Data: Concepts of population and sample, quantitative and qualitative data, cross-sectional and time-series data, discrete and continuous data. Different types of scales: Nominal, ordinal, interval and ratio. Collection and Scrutiny of Data: Primary data. Secondary data – its major sources. Complete enumeration. Construction of tables with one or more factors of classification, frequency distributions and cumulative frequency distributions and their graphical representations (Histograms, frequency polygon), stem and leaf displays.

#### **Unit – 2**

**(15 hours)**

##### **Data Summarization**

Measures of Central Tendency: Mathematical and positional, partition values, Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, graphical representation of various measures of location and dispersion (Ogives, Histograms, Box Plot) Moments: Raw moments, Central moments, Absolute moments, Factorial moments, Sheppard's corrections, skewness and kurtosis, Types of frequency distributions.

#### **Unit – 3**

**(06 hours)**

##### **Theory of Attributes**

Theory of attributes: consistency and independence of data with special reference to attributes, Association of attributes: concept, Yules coefficient of Colligation and Coefficient of Colligation.

#### **Unit – 4**

**(15 hours)**

##### **Correlation and Regression**

Bivariate data: Definition, scatter diagram, Karl Pearson's coefficient of correlation. Spearman's rank correlation coefficient (Introductory with interpretation). Principle of least squares and fitting of polynomials and exponential curves, lines of regression, properties of regression coefficients, angle between two regression lines, and residual variance.

### **Practical – 30 Hours**

#### **List of Practicals:**

1. Graphical representation of data- frequency polygon, histogram and ogive.
2. Practical based on arithmetic mean and to find missing frequencies given arithmetic mean.
3. Practical based on median and partition values using formulae and to find them graphically also.
4. Practical based on mode by using formula, graphically, method of grouping.
5. Practical based on combined mean and combined variance.
6. Practical based on quartile deviation using formula and graphically.
7. Practical based on mean deviation and standard deviation.
8. Practical based on coefficient of variation.
9. Practical based on moments about origin and moments about any arbitrary point.
10. Practical on skewness based on mean, median, mode and standard deviation.
11. Practical based on central moments, skewness and kurtosis.
12. Practical based on fitting of polynomials.
13. Practical based on fitting of exponential curves, power curves.
14. Practical based on association and independence of attributes.
15. Practical based on fundamental set of class frequencies in attributes (find missing frequencies given fundamental set of class frequencies).
16. Practical based on Karl Pearson correlation coefficient.
17. Practical based on correlation coefficient for a bivariate frequency distribution.
18. Practical based on lines of regression, angle between lines and estimated values of variables.
19. Practical based on rank correlation with ties.
20. Practical based on rank correlation without ties.

#### **Essential Readings**

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I, 8th Ed. The World Press, Kolkata.
- Gupta, S. C. and Kapoor, V. K. (2020). Fundamentals of Mathematical Statistics, 12th Edn., S. Chand and Sons. Delhi.
- Bernstein, S. and Bernstein, R. (2020). Schaums: Outline of Elements of Statistics I Descriptive Statistics and Probability. McGraw Hill.
- Heumann, C., Schomaker, M. and Shalabh (2016). Introduction to Statistics and Data Analysis with Exercises, Solutions and Applications in R. Springer.

### Suggestive Readings

- Tukey, J.W. (1977). Exploratory Data Analysis, Addison-Wesley Pub. Co. N.Y.
- Myatt, G, J. and Johnson, W.P. (2014). Making sense of data: A practical guide to exploratory data analysis and data mining. 2nd Edn, John Wiley & Sons, Inc. N. J.
- Agresti, A., Christine Franklin, C. and Klingenberg, B. (2017). Statistics: the art and science of learning from data. Pearson. Boston.
- Dudewicz, E. and Mishra, S. N. (1988). Modern Mathematical Statistics. Wiley.

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

## DISCIPLINE SPECIFIC CORE COURSE – 2: INTRODUCTION TO 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		
Introduction to Probability	4	3	0	1	Class XII pass with Mathematics	NIL

### Learning Objectives

The Learning Objectives of this course are as follows:

- Familiarize students with the mathematical basis of probability theory.
- Prepare students with important tools for statistical analyses at the undergraduate level.
- Promote understanding through real-world statistical applications.

### Learning Outcomes

The Learning Outcomes of this course are as follows:

- Understand the meaning of probability and probabilistic experiment. Familiarize with the four approaches to probability theory and particularly, the axiomatic approach, use and manipulate the four axioms of probability comfortably to derive the results of other set operations.
- Understand and use addition and multiplicative laws of probability, understand the meaning of conditional probability, conditioning, and reduced sample space, compute joint and conditional probabilities. independence, total probability, Bayes' rule and applications.
- Understand the concept of a random variable, differentiate between independent and uncorrelated random variables, distinguish between discrete and continuous, random variables and be able to represent them using probability mass, probability density, and

cumulative distribution functions. Acquaint with Univariate transformation and its application.

- Understand expectation and its properties, Compute variance and covariance in terms of expectation. Solve problems based on expectation and its properties.

## **SYLLABUS OF DSC - 2**

### **Theory**

#### **Unit – 1 (12 hours)**

##### **Elements of Probability**

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – Classical, Statistical. Limitations of Classical definition. Probability of union and intersection of events, Probability of occurrence of exactly  $m$  and at least  $m$  events out of  $n$  events, Examples based on classical approach and repeated trials, Kolmogorov's Axiomatic definition and problems based on it, Matching problems.

#### **Unit – 2 (09 hours)**

##### **Laws of Probability**

Conditional Probability, laws of addition and multiplication, theorem of total probability, Examples based on conditional probability and laws of addition and multiplication, independent events – Pairwise mutual independence, Bayes' theorem and its applications, Geometric probability.

#### **Unit – 3 (15 hours)**

##### **Random variables**

Distribution function and properties, Discrete random variables - p.m.f., discrete distribution function, Continuous random variables - p.d.f, illustrations and properties of random variables. Measures of central tendency, dispersion, skewness and kurtosis for continuous probability distributions, Examples based on random variables, Continuous distribution functions and their properties, Univariate transformation of random variables, Examples based on univariate transformations.

#### **Unit – 4 (09 hours)**

##### **Mathematical Expectation**

Expectation of random variable and its properties (addition and multiplication theorem of expectation), Variance and Covariance in terms of expectation and their properties, Examples based on Expectation and its properties.

### **Practical – 30 Hours**

#### **List of Practicals:**

1. Problem based long run relative frequency to establish statistical definition of probability
2. Problem based on geometric probability.

3. Problem based on permutations and combinations when all objects are distinguishable.
4. Problem based on permutations and combinations when not all objects are different.
5. Computation of probability related to occurrence of exactly  $m$  and at least  $m$  events out of  $n$  events.
6. Computation of probabilities related to matching problems
7. Computation of conditional probabilities using addition and multiplication laws.
8. Problem related to application of Bayes Theorem.
9. Computation of distribution function of discrete and continuous random variables and calculations of probabilities of events thereof.
10. Graphical representation of probability function and distribution function of discrete/continuous arbitrary random variables.
11. Finding expectation, variance and covariances of discrete as well as continuous random variables
12. Finding expectation, variance and covariances of linear function of discrete as well as continuous random variables.
13. Constructing sample space for two-dimensional random variable.

### **Essential Readings**

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I, 8th Ed. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2017). 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.
- Ross, S.M. (2002). A first course in Probability, 6th Ed., Pearson.
- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia.

### **Suggestive Readings**

- Chung, K.L. (2000). A Course in Probability Theory, 3rd Edn. Academic Press.
- Parzen, E. (1960). Modern probability theory and its applications. John Wiley.
- Feller, W. (1968) An introduction to probability theory and its applications. Vol. I, 3rd Edn. John Wiley & Sons Inc., New York.
- Blake, I. F. (1987). Introduction to Applied Probability. Krieger Publishing Co.

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

## DISCIPLINE SPECIFIC CORE COURSE – 3: 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	0	1	Class XII pass with Mathematics	NIL

#### Learning Objectives

The Learning Objectives of this course are as follows:

- To familiarize students with the basic mathematical tools.
- It helps students to understand the other statistical concepts.

#### Learning Outcomes

The Learning Outcomes of this course are as follows:

- Understand to solve applied problems using differentiation and integration.
- Understand to solve applied problems under integral sign and changes of order of integration.

### SYLLABUS OF DSC – 3

#### Theory

#### Unit – 1 (15 hours)

##### Differential Calculus

Review of limits, continuity and differentiability, partial differentiation and total differentiation. Indeterminate forms: L-Hospital's rule, Leibnitz rule for successive differentiation. Euler's theorem on homogeneous functions.

#### Unit – 2 (15 hours)

##### Integral Calculus

Review of integration and definite integral. Differentiation under integral sign, double integral, changes of order of integration. Beta and Gamma functions: Properties and relationship between them.

#### Unit – 3 (15 hours)

##### Differential Equations

Exact differential equations. Differential equations of first order and first degree. Higher Order Differential Equations: Linear differential equations of order n, Homogeneous and non-

homogeneous linear differential equations of order  $n$  with constant coefficients, Different forms of particular integrals. The Cauchy-Euler's equation of order  $n$ . Formation and solution of a partial differential equations. Equations easily integrable. Linear partial differential equations of first order. Homogeneous linear partial differential equations with constant coefficients. Different cases for complimentary functions and particular integrals.

## Practical – 30 Hours

List of Practicals:

- 1) Verification of Euler's Theorem.
- 2) Applications of differentiation
  - a. Calculate income and price elasticity of demand.
  - b. Determination of price and quantity for which total revenue is maximum.
  - c. Find the level of output for which the average cost is minimum.
  - d. Solve profit maximization problems.
  - e. Evaluate first and second order partial derivatives of functions of the form  $Z = f(x, y)$ .
  - f. Examine a function of two variables for relative maxima and relative minima.
  - g. Find the nature of the commodities by using the concept of partial marginal demand functions.
  - h. Find four partial elasticities for a demand function of two variables.
- 3) Applications of Integration
  - a) Derive total cost function from given marginal cost function.
  - b) Derive total revenue function and demand function from a given marginal revenue function.
  - c) Calculate the maximum profit if marginal revenue and marginal cost are given.
  - d) Find the demand function when the price elasticity of demand is given.
- 4) Applications of Differential Equations
  - a) Application on growth and decay.
  - b) Application of the form  $\frac{d^2y}{dx^2} = f(x)$  and  $\frac{d^2y}{dx^2} = f(y)$  to physical problems.
  - c) Application on coordinate geometry.
- 5) Verify that the area under the curve is unity under the given p.d.f. and also calculate
  - a) Arithmetic Mean
  - b) Median
  - c) Mode
  - d) Standard Deviation

## Essential Reading

- Prasad, G. (2017). Differential Calculus, 19th Ed. (Revised), Pothishala Pvt. Ltd., Allahabad.
- Prasad, G. (2017). Integral Calculus, 17th Ed. (Revised), Pothishala Pvt. Ltd., Allahabad.
- Ahsan, Z. (2004). Differential Equations and their Applications, 2nd Ed., PHI, Pvt. Ltd., New Delhi.
- Shanti Narayan and P K Mittal (2018). Differential Calculus. 15th Ed (Revised), S Chand Publication, New Delhi
- Shanti Narayan and P K Mittal (2016). Integral Calculus. 11th Ed (Revised), S Chand Publication, New Delhi.



- Business Mathematics Theory and Applications, V. K. Kapoor (2012), Sultan Chand & Sons.

### **Suggestive Reading**

- R. S. Soni (2000) Business Mathematics with applications in Business and Economics, 3<sup>rd</sup> ed., Pitamber Publishing Company (P) Ltd.
- Brahma Nand, B. S. Tyagi and B. D. Sharma, Integral Calculus, Kedar Nath Ram Nath.

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

## **B.A (Program) with Statistics as Major**

### **Category II**

#### **DISCIPLINE SPECIFIC CORE COURSE – 1: DESCRIPTIVE 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		
Descriptive Statistics	4	3	0	1	Class XII pass with Mathematics	Nil

#### **Learning Objectives**

The Learning Objectives of this course are as follows:

- To motivate students towards intrinsic interest in statistical thinking.
- To analyze and interpret data.

#### **Learning outcomes**

The Learning Outcomes of this course are as follows:

- Understand the basic concepts of Statistics.
- Able to employ different types of data.
- Employ the graphical methods of displaying data.
- Use measures of locations.

#### **SYLLABUS OF DSC - 1**

##### **Theory**

##### **Unit – 1**

**(15 hours)**

##### **Data Representation**

Introduction: Definition, importance, scope and limitations of Statistics. Population and Sample Concept of statistical population with illustrations, concept of sample with illustrations. Raw data, Attributes and variables, discrete and continuous variables, classification and construction of frequency distribution. Graphical Representation: Histogram, Frequency polygon, Frequency curve, Ogive curves and their uses. Examples and Problems.

##### **Unit – 2**

**(15 hours)**

##### **Measures of central tendency**

Concept of central tendency, Criteria for good measures of central tendency. Arithmetic mean: Definition, computation for ungrouped and grouped data, combined mean, weighted mean,

merits and demerits. Median: Definition, computation for ungrouped and grouped data, graphical method, merits and demerits. Mode: Definition, computation for ungrouped and grouped data, graphical method, merits and demerits. Quartiles: Definition, computation for ungrouped and grouped data graphical method. Numerical problems.

### **Unit – 3**

**(15 hours)**

#### **Measures of Dispersion**

Concept of dispersion and measures of dispersion, absolute and relative measures of dispersion. Range and Quartile Deviation: definition for ungrouped and grouped data, and their coefficients, merits and demerits. Mean Deviation: Definition for ungrouped and grouped data, minimal property (statement only). Standard deviation and Variance: definition for ungrouped and grouped data, coefficient of variation, combined variance and standard deviation for two groups, merits and demerits. Numerical problems.

#### **Practical**

##### **List of Practicals:**

1. Problems based on graphical representation of data: Histograms, Frequency polygon, Ogive curve for equal class intervals.
2. Problems based on graphical representation of data: Histograms, Frequency polygon, Ogive curve for unequal class intervals.
3. Problems based on measures of central tendency using raw data, grouped data.
4. Problems based on change of origin and scale.
5. Problems based on measures of dispersion using raw data, grouped data.
6. Problems based on measures of dispersion for change of origin and scale.
7. Problems based on combined mean.
8. Problems based on combined variance.
9. Problems based on coefficient of variation.
10. Problems based on standard deviation of two groups

##### **Essential Readings**

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). Fundamentals of Statistics, Vol. I, 8th Ed. The World Press, Kolkata.
- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia.
- 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.

##### **Suggestive Reading**

- Gupta, S.P. (2022) Statistical Methods 46<sup>th</sup> ed, S. Chand and Sons
- Gupta, S. C. and Kapoor V. K. (). Fundamentals of Mathematical Statistics, S. Chand and Sons

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

## DISCIPLINE SPECIFIC CORE COURSE – 2: STATISTICAL METHODS

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

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

### Learning Objectives

The Learning Objectives of this course are as follows:

- Acquainting the students with various statistical methods.
- Students should be able to understand and compute various statistical measures of correlation, fitting of curve and regression.

### Learning Outcomes

Upon successful completion of this course students will demonstrate knowledge of:

- Correlation and regression.
- Theory of attributes.

## SYLLABUS OF DSC - 2

### Theory

#### Unit – 1 (15 hours)

##### Correlation

Introduction and meaning of Correlation, Scatter diagram, Karl Pearson's coefficient of correlation, limits for correlation coefficient, correlation coefficient for bivariate distribution, rank correlation: tied and repeated rank, correlation ratio, measure of correlation ratio, Intra class correlation, multiple and partial correlation.

#### Unit – 2 (15 hours)

##### Regression

Introduction to Linear regression, regression coefficient, properties of regression coefficients, angle between two lines of regression, regression curve, curvilinear regression. Principle of least-squares and fitting of polynomials and exponential curves.

#### Unit – 3 (15 hours)

##### Theory of Attributes

Theory of attributes: Notion and terminology, class frequencies, ultimate class frequencies, Contingency table, consistency, association of attributes, independence, measure of association for 2x2 table, Yule's coefficient of association.

### **Practical – 30 Hours**

#### **List of Practicals:**

1. Problems based on Karl Pearson correlation coefficient.
2. Problems based on Karl Pearson correlation coefficient with change of scale and origin.
3. Problem based on multiple correlation
4. Problem based on partial correlation
5. Problems based on lines of regression.
6. Problems based on angle between two lines of regression.
7. Problems based on Spearman rank correlation.
8. Problems based on fitting of polynomials and exponential curves.
9. Problems based on association and independence of attributes.
10. Problems based on fundamental set of class frequencies in attributes (find missing frequencies given fundamental set of class frequencies)

#### **Essential Readings**

- Goon, A. M., Gupta, M. K. and Dasgupta, B. (2003). An Outline of Statistical Theory (4th ed., Vol. I). World Press, Kolkata.
- Gupta, S. C. and Kapoor, V. K. (2007). Fundamentals of Mathematical Statistics (11th ed.). Sultan Chand and Sons.
- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia.

#### **Suggestive Readings**

- Gupta, S.P. (2022) Statistical Methods 46<sup>th</sup> ed, S. Chand and Sons
- Hogg, R. V., Craig, A. T. and McKean, J. W. (2005). Introduction to Mathematical Statistics (6th ed.). Pearson Education

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

## **B.A. (Program) with Statistics as Minor**

### **Category III**

#### **DISCIPLINE SPECIFIC CORE COURSE: DESCRIPTIVE STATISTICS AND PROBABILITY THEORY**

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

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

#### **Learning Objectives**

The Learning Objectives of this course are as follows:

- Introduction to Statistics.
- Graphical representation of data.
- Understanding the concept of Probability.

#### **Learning outcomes**

The Learning Outcomes of this course are as follows:

- Apply the fundamental concepts of statistics.
- Understand handling various types of data and their graphical representation.
- Employ measures of location and dispersion.
- Bivariate data. Significance of various coefficients of correlation.
- Employ fitting of linear curve.
- Use probability theory and its applications.

#### **SYLLABUS OF DSC**

##### **Theory**

##### **Unit – 1**

**(15 hours)**

##### **Basic Statistics**

Fundamentals of statistics. Diagrammatic representation of data. Measures of central tendency: location and positional. Partition values, Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation. Moments: raw and central, Measures of skewness and kurtosis.

## **Unit – 2**

**(15 hours)**

### **Correlation and Regression**

Bivariate data: definition, scatter diagram. Correlation and regression: Karl Pearsons coefficient of correlation, Spearman's rank correlation coefficient, lines of regression, properties of regression coefficients, angle between two regression lines. Principle of least-square and fitting of linear curve.

## **Unit – 3**

**(15 hours)**

### **Probability**

Probability: Introduction, Random experiment, sample point and sample space, event, algebra of events, Definition of Probability - classical, relative frequency and axiomatic approaches to probability, merits and demerits of these approaches (only general ideas to be given). Theorems on probability, conditional probability, independent events: pairwise and mutually independent. Bayes theorem and its applications.

### **Practical – 30 Hours**

#### **List of Practicals:**

1. Problems based on graphical representation of data. Histograms (equal class intervals and unequal class intervals), frequency polygon, ogive curve.
2. Problems based on mean using raw data, grouped data for change of origin and scale.
3. Problems based on arithmetic mean and to find missing frequencies given arithmetic mean.
4. Problems based on median and partition vales using formulae and to find them graphically also.
5. Problems based on mode by using formula, graphically, method of grouping.
6. Problems based on mean deviation and standard deviation.
7. Problems based on combined mean and variance.
8. Problems based on coefficient of variation.
9. Comparison of data using consistency approach.
10. Problems on skewness based on mean, median, mode and standard deviation.
11. Problems based on central moments.
12. Relationships between moments about origin and central moments.
13. Problems based on skewness and kurtosis.
14. Problems based on Karl Pearson correlation coefficient.
15. Problems based on Spearman's rank correlation with ties.
16. Problems based on Spearman's rank correlation without ties.
17. Problems based on lines of regression and estimated values of variables.
18. Problems on regression coefficients.

#### **Essential Readings**

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). Fundamentals of Statistics, Vol. I, 8th Ed., World Press, Kolkatta.
- Gupta, S.C. and Kapoor, V.K. (2014). Fundamentals of Mathematical Statistics, 11th Ed., Sultan Chand and Sons.

- Hogg, R. V., McKean, J., and Craig, A. T. (2005). Introduction to mathematical statistics. Pearson Education.
- Freund, J.E. (2009). Mathematical Statistics with Applications, 7th Ed., Pearson Education.

### **Suggestive Readings**

- Mood, A.M., Graybill, F.A. and Boes, D.C. (2007). Introduction to the Theory of Statistics, 3rd Ed., Tata McGraw Hill Publication
- Miller, Irwin and Miller, Marylees (2006): John E Freund's Mathematical Statistics with Applications, (7<sup>th</sup> ed.) Pearson Education, Asia.
- Nagar and Das (1997) Basic Statistics. 2<sup>nd</sup> ed., Oxford University Press

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



## **B.A. (Prog.) Multidisciplinary Studies with Statistics**

### **DISCIPLINE SPECIFIC CORE COURSE: DESCRIPTIVE 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		
Descriptive Statistics	4	3	0	1	Class XII pass with Mathematics	Nil

#### **Learning Objectives**

The Learning Objectives of this course are as follows:

- To motivate students towards intrinsic interest in statistical thinking.
- To analyze and interpret data.

#### **Learning outcomes**

The Learning Outcomes of this course are as follows:

- Understand the basic concepts of Statistics.
- Able to employ different types of data.
- Employ the graphical methods of displaying data.
- Use measures of locations.

#### **SYLLABUS OF DSC**

##### **Theory**

##### **Unit – 1**

**(15 hours)**

##### **Basics of Statistics**

Introduction: Definition, importance, scope and limitations of Statistics. Population and Sample Concept of statistical population with illustrations, concept of sample with illustrations. Raw data, Attributes and variables, discrete and continuous variables, classification and construction of frequency distribution. Graphical Representation: Histogram, Frequency polygon, Frequency curve, Ogive curves and their uses. Examples and Problems.

##### **Unit – 2**

**(15 hours)**

##### **Measures of Central Tendency**

Concept of central tendency, Criteria for good measures of central tendency. Arithmetic mean: Definition, computation for ungrouped and grouped data, combined mean, weighted mean, merits and demerits. Median: Definition, computation for ungrouped and grouped data, graphical method, merits and demerits. Mode: Definition, computation for ungrouped and grouped data,

graphical method, merits and demerits. Quartiles: Definition, computation for ungrouped and grouped data graphical method. Numerical problems.

### **Unit – 3**

**(15 hours)**

#### **Measures of Dispersion**

Concept of dispersion, absolute and relative measures of dispersion. Range and Quartile Deviation: definition for ungrouped and grouped data, and their coefficients, merits and demerits. Mean Deviation: Definition for ungrouped and grouped data, minimal property (statement only). Standard deviation and Variance: definition for ungrouped and grouped data, coefficient of variation, combined variance and standard deviation for two groups, merits and demerits. Numerical problems.

#### **Practical**

##### **List of Practicals:**

1. Problems based on graphical representation of data: Histograms, Frequency polygon, Ogive curve for equal class intervals.
2. Problems based on graphical representation of data: Histograms, Frequency polygon, Ogive curve for unequal class intervals.
3. Problems based on measures of central tendency using raw data, grouped data.
4. Problems based on change of origin and scale.
5. Problems based on measures of dispersion using raw data, grouped data.
6. Problems based on measures of dispersion for change of origin and scale.
7. Problems based on combined mean.
8. Problems based on combined variance.
9. Problems based on coefficient of variation.
10. Problems based on standard deviation of two groups

##### **Essential Readings**

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). Fundamentals of Statistics, Vol. I, 8th Ed. The World Press, Kolkata.
- 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.
- Gupta, S.C., and Kapoor, V.K. (2014). Fundamental of Mathematical Statistics, 11<sup>th</sup> Ed., Sultan Chand

##### **Suggestive Reading**

- Gupta, S.P. (2022) Statistical Methods 46<sup>th</sup> ed, S. Chand and Sons
- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia.

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

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

**GENERIC ELECTIVES: INTRODUCTION TO 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		
Introduction to Statistics	4	3	0	1	Class XII pass with Mathematics	NIL

**Learning Objectives**

The Learning Objectives of this course is as follows:

- Acquainting the students with descriptive data analysis.
- To introduce students to different measurement scales, qualitative and quantitative and discrete and continuous data.
- To help students to organise data into frequency distribution graphs, including bar graphs, histograms, polygons and ogives.
- Students should be able to understand the purpose for measuring central tendency, dispersion, skewness and kurtosis and should be able to compute them as well.
- Students should be able to understand theory of attributes, independence and association of attributes.

**Learning Outcomes**

The Learning Outcomes of this course are as follows:

- Introduction to Statistics, definitions and data classification
- Employ graphical displays of data, frequency distributions, analysing graphs.
- Apply numerical descriptions of data, measures of center tendency, measures of dispersion, skewness and kurtosis.
- Understand theory of attributes.

**SYLLABUS OF GE**

**Theory**

**Unit – 1**

**(15 hours)**

## **Introduction to Statistics and Data**

Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement -nominal, ordinal, interval and ratio. Presentation: tabular and graphic, including histogram and ogives.

### **Unit – 2**

**(15 hours)**

#### **Descriptive Statistics**

Measures of Central Tendency: Arithmetic mean, median, mode, geometric mean, harmonic mean, partition values. Measures of Dispersion: Range, quartile deviation, mean deviation, standard deviation, variance, coefficient of dispersion: coefficient of variation. Moments, Measure of skewness and kurtosis.

### **Unit – 3**

**(15 hours)**

#### **Theory of Attributes**

Theory of Attributes: Consistency of data, independence of attributes, association of attributes, Yule's coefficient of association, coefficient of colligation.

### **Practical – 30 Hours**

#### **List of Practicals:**

1. Tabular representation of data
2. Graphical representation of data using histogram
3. Graphical representation of data using ogives
4. Problems based on arithmetic mean
5. Problems based on geometric mean
6. Problems based on harmonic mean
7. Problems based on median
8. Problems based on mode
9. Problems based on partition values
10. Verifying the relationship between arithmetic mean, geometric mean and harmonic mean
11. Problems based on range and quartile deviation.
12. Problems based on mean deviation
13. Problems based on standard deviation and variance
14. Problems based on combined mean and combined variance
15. Problems based on coefficient of variation.
16. Problems based on moments,
17. Problems based on skewness
18. Problems based on kurtosis
19. Checking consistency of data.
20. Checking the independence of attributes
21. Measuring the association between the attributes

#### **Essential Readings**

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). Fundamentals of Statistics, 8th Ed. Vol. I & II, The World Press, Kolkata.

- 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.
- Gupta, S.C., and Kapoor, V.K. (2014). Fundamental of Mathematical Statistics, 11th Ed., Sultan Chand.

### **Suggestive Reading**

- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia.
- Ross, Sheldon M. (2010): Introductory Statistics, 3rd Edition, Academic Press

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

## **GENERIC ELECTIVES: TIME SERIES ANALYSIS AND INDEX NUMBERS**

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

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

### **Learning Objectives**

The Learning Objectives of this course are as follows:

- Introduce the concept of time series, its components, and their estimation.
- Introduce the application of time series.
- Introduce the concept, formulation, and application of index numbers.

### **Learning outcomes**

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

- Understand the concepts of time series and index numbers.
- Formulate, solve, and analyze the use of time series and index numbers for real-world problems.

## **SYLLABUS OF GE**

### **Theory**

#### **Unit - 1**

**(15 hours)**

## **Components of Time Series**

Introduction to Time Series, Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series, Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and exponential).

## **Unit - 2**

**(15 hours)**

### **Trend and Seasonality**

Fitting of modified exponential, Gompertz and logistic curve, Moving average method, Measurement of seasonal variations by method of simple averages, ratio to trend method, and ratio to moving average method.

## **Unit - 3**

**(15 hours)**

### **Index Numbers**

Introduction to Index numbers, Problems in the construction of index numbers, Construction of price and quantity index numbers: simple aggregate, weighted aggregate (Laspeyres, Paasche's, Drobish-Bowley, Marshall-Edgeworth's, Walsch and Fisher's Formula), simple and weighted average of price relatives, and chain base method, Criteria for a good index number, Errors in the measurement of price and quantity index numbers, Consumer price index number, its construction and uses, Uses and limitations of index numbers.

## **Practical – 30 Hours**

### **List of Practicals:**

- a. Fitting of linear trend
- b. Fitting of quadratic trend
- c. Fitting of an exponential curve
- d. Fitting of modified exponential curve by the method of
  - Three selected points
  - Partial sums
- e. Fitting of Gompertz curve by the method of
  - Three selected points
  - Partial sums
- f. Fitting of logistic curve by the method of three selected points
- g. Fitting of trend by moving average method (for n even and odd)
- h. Measurement of seasonal indices by
  - Method of simple averages
  - Ratio-to-trend method
  - Ratio-to-moving-average method
- i. Construction of price and quantity index numbers by simple aggregate method.
4. Construction of price and quantity index numbers by Laspeyres, Paasche's, Drobish-Bowley, Marshall-Edgeworth, Walsch and Fisher's Formula.
5. Construction of price and quantity index numbers by simple and weighted average of price relatives.
6. Construction of index number by Chain base method.
7. Construction of consumer price index number by

- a. Family budget method
  - b. Aggregate expenditure method
14. Time Reversal Test and Factor Reversal Test

### 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 Ed., World Press, Kolkata.
- Gupta, S.C. and Kapoor, V.K. (2014). Applied Statistics, 11<sup>th</sup> Ed., Sultan Chand.

### Suggestive Reading

- Allen R.G.D. (1975): Index Numbers in Theory and Practice, Macmillan
- Mukhopadhyay, P. (1999). Applied Statistics, New Central Book Agency, Calcutta.

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

## GENERIC ELECTIVES: BASIC 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		
Basic Statistics	4	3	0	1	Class XII pass with Mathematics	NIL

### Learning Objectives

The Learning Objectives of this course are as follows:

- To summarize the data and to obtain its salient features from the vast mass of original data.
- To understand the concepts of probability and its applications.
- To understand the concept of random variables, probability distributions and expectation..

### Learning outcomes

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

- Apply the concepts of statistical population and sample, variables and attributes.
- Present tabular and graphical representation of data based on variables.
- Measures of central tendency, Dispersion, Skewness and Kurtosis.
- Employ moments and their use in studying various characteristics of data.

- Employ correlation and regression analysis of bivariate data.

## **SYLLABUS OF GE**

### **Theory**

#### **Unit - 1 (15 hours)**

##### **Elementary Statistics**

Concepts of a statistical population and sample from a population, quantitative and qualitative data, nominal, ordinal and time-series data, discrete and continuous data. Presentation of data by tables and by diagrams, frequency distributions for discrete and continuous data, graphical representation of a frequency distribution by histogram and frequency polygon, cumulative frequency distributions (inclusive and exclusive methods).

#### **Unit - 2 (15 hours)**

##### **Descriptive Statistics**

Measures of location (or central tendency) and dispersion, moments, measures of skewness and kurtosis, cumulants. Bi-variate data: Scatter diagram, principle of least-squares and fitting of polynomials and exponential curves.

#### **Unit - 3 (15 hours)**

##### **Correlation and Regression**

Bivariate data: Definition, scatter diagram, simple, partial and multiple correlation (3 variables only), rank correlation. Simple linear regression, principle of least squares and fitting of polynomials and exponential curves.

### **Practical - 30 Hours**

#### **List of Practicals:**

1. Problems based on graphical representation of data.
2. Problems based on measures of central tendency using raw data, grouped data and for change of origin and scale.
3. Problems based on measures of dispersion using raw data, grouped data and for change of origin and scale.
4. Problems based on combined mean and variance and coefficient of variation.
5. Problems based on Moments using raw data, grouped data and for change of origin and scale.
6. Problems based on relationships between moments about origin and central moments.
7. Problems based on Skewness and kurtosis.
8. Problems based on Karl Pearson correlation coefficient (with/without change of scale and origin).
9. Problems based on Lines of regression, angle between two lines of regression
10. Problems based on Spearman rank correlation.
11. Fitting of polynomials and exponential curves.



**Essential Readings**

- Goon, A. M., Gupta, M. K. and Dasgupta, B. (2003). An Outline of Statistical Theory (4th ed., Vol. I). World Press, Kolkata.
- Gupta, S. C. and Kapoor, V. K. (2021). Fundamentals of Mathematical Statistics (60<sup>th</sup> ed.). Sultan Chand and Sons.
- Hogg, R. V., Craig, A. T. and McKean, J. W. (2005). Introduction to Mathematical Statistics (6th ed.). Pearson Education.

**Suggestive Reading**

- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia
- Elhance, D. N. , Elhance, V. and Agrawal, B. M. ( 2021), Kitab Mahal

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

## DEPARTMENT OF COMPUTER SCIENCE

### B.Sc. (H) Computer Science

#### *CATEGORY-I*

#### DISCIPLINE SPECIFIC CORE COURSE – 1: PROGRAMMING 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		
Programming using Python	4	3	0	1	Class XII pass	Nil

#### Learning Objectives

This course is designed as the first course that:

- Introduces programming concepts using Python to Computer Science students.
- Focuses on the development of Python programming to solve problems of different domains.
- Introduces the concept of object- oriented programming.

#### Learning Outcomes:

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

- Understand the basics of programming language
- Develop, document, and debug modular Python programs.
- Apply suitable programming constructs and built-in data structures to solve a problem.
- Use and apply various data objects in Python.
- Use classes and objects in application programs and handle files.

#### SYLLABUS OF DSC-1

##### Theory

##### Unit – 1

(6 hours)

##### Introduction to Programming

Problem solving strategies; Structure of a Python program; Syntax and semantics; Executing simple programs in Python.

**(12 hours)**

Identifiers and keywords; Literals, numbers, and strings; Operators; Expressions; Input/output statements; Defining functions; Control structures (conditional statements, loop control statements, break, continue and pass, exit function), default arguments.

**(15 hours)**

Mutable and immutable objects; Strings, built-in functions for string, string traversal, string operators and operations; Lists creation, traversal, slicing and splitting operations, passing list to a function; Tuples, sets, dictionaries and their operations.

**(6 hours)**

Introduction to classes, objects and methods; Standard libraries.

**(6 hours)**

## File handling through libraries; Errors and exception handling.

**(30 hours)**

1. WAP to find the roots of a quadratic equation
2. WAP to accept a number 'n' and
  - j. Check if 'n' is prime
  - k. Generate all prime numbers till 'n'
  - l. Generate first 'n' prime numbersThis program may be done using functions
3. WAP to create a pyramid of the character '\*' and a reverse pyramid

8. WAP that accepts a character and performs the following:
  - a. print whether the character is a letter or numeric digit or a special character
  - b. if the character is a letter, print whether the letter is uppercase or lowercase

- c. if the character is a numeric digit, prints its name in text (e.g., if input is 9, output is NINE)
- 9. WAP to perform the following operations on a string
  - a. Find the frequency of a character in a string.
  - b. Replace a character by another character in a string.
  - c. Remove the first occurrence of a character from a string.
  - d. Remove all occurrences of a character from a string.
- 10. WAP to swap the first n characters of two strings.
- 11. Write a function that accepts two strings and returns the indices of all the occurrences of the second string in the first string as a list. If the second string is not present in the first string then it should return -1.
- 12. WAP to create a list of the cubes of only the even integers appearing in the input list (may have elements of other types also) using the following:
  - a. 'for' loop
  - b. list comprehension
- 13. WAP to read a file and
  - m. Print the total number of characters, words and lines in the file.
  - n. Calculate the frequency of each character in the file. Use a variable of dictionary type to maintain the count.
  - o. Print the words in reverse order.
  - p. Copy even lines of the file to a file named 'File1' and odd lines to another file named 'File2'.
- 14. WAP to define a class Point with coordinates x and y as attributes. Create relevant methods and print the objects. Also define a method distance to calculate the distance between any two point objects.
- 15. Write a function that prints a dictionary where the keys are numbers between 1 and 5 and the values are cubes of the keys.
- 16. Consider a tuple t1=(1, 2, 5, 7, 9, 2, 4, 6, 8, 10). WAP to perform following operations:
  - a. Print half the values of the tuple in one line and the other half in the next line.
  - b. Print another tuple whose values are even numbers in the given tuple.
  - c. Concatenate a tuple t2=(11,13,15) with t1.
  - d. Return maximum and minimum value from this tuple
- 17. WAP to accept a name from a user. Raise and handle appropriate exception(s) if the text entered by the user contains digits and/or special characters.

### Essential Readings

- Taneja, S., Kumar, N. Python Programming- A modular Approach, 1st edition, Pearson Education India, 2018.
- Balaguruswamy E. Introduction to Computing and Problem Solving using Python, 2nd edition, McGraw Hill Education, 2018.

### Suggestive Readings

- Brown, Martin C. Python: The Complete Reference, 2nd edition, McGraw Hill Education, 2018.
- Gutttag, J.V. Introduction to computation and programming using Python, 2nd edition, MIT Press, 2016.

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

## DISCIPLINE SPECIFIC CORE COURSE – 2: COMPUTER SYSTEM ARCHITECTURE

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

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

### Learning Objectives

The Learning Objectives of this course are as follows:

- Introduces the students to the fundamental concepts of digital computer organization, design and architecture.
- Develop a basic understanding of the building blocks of the computer system and highlights how these blocks are organized together to architect a digital computer system.

### Learning Outcomes

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

- Design Combinational Circuits using basic building blocks. Simplify these circuits using Boolean algebra and Karnaugh maps. Differentiate between combinational circuits and sequential circuits.
- Represent data in binary form, convert numeric data between different number systems and perform arithmetic operations in binary.
- Determine various stages of instruction cycle, pipelining and describe interrupts and their handling.

- Explain how CPU communicates with memory and I/O devices and distinguish between different types of processors.
- Simulate the design of a basic computer using a software tool.

## **SYLLABUS OF DSC - 2**

### **Theory**

#### **Unit – 1 (6 hours)**

##### **Digital Logic Circuits**

Logic Gates, Truth Tables, Boolean Algebra, Digital Circuits, Combinational Circuits, Introduction to Sequential Circuits, Circuit Simplification using Karnaugh Map, Don't Care Conditions, Flip-Flops, Characteristic Tables, Excitation Table.

#### **Unit – 2 (9 hours)**

##### **Digital Components (Fundamental building blocks)**

Designing of combinational circuits- Half Adder, Full Adder, Decoders, Encoders, Multiplexers, Registers and Memory (RAM, ROM and their types), Arithmetic Microoperations, Binary Adder, Binary Adder-Subtractor.

#### **Unit – 3 (6 hours)**

##### **Data Representation and Basic Computer Arithmetic**

Number System,  $r$  and  $(r-1)$ 's Complements, data representation and arithmetic operations.

#### **Unit – 4 (9 hours)**

##### **Basic Computer Organization and Design**

Bus organization, Microprogrammed vs Hardwired Control, Instruction Codes, Instruction Format, Instruction Cycle, Instruction pipelining, Memory Reference, Register Reference and Input Output Instructions, Program Interrupt and Interrupt Cycle..

#### **Unit – 5 (6 hours)**

##### **Processors**

General register organization, Stack Organization, Addressing Modes, Overview of Reduced Instruction Set Computer (RISC), Complex Instruction Set Computer (CISC), Multicore processor and Graphics Processing Unit (GPU).

#### **Unit – 6 (9 hours)**

##### **Memory and Input-Output Organization**

Memory hierarchy (main, cache and auxiliary memory), Input-Output Interface, Modes of Transfer: Programmed I/O, Interrupt initiated I/O, Direct memory access.

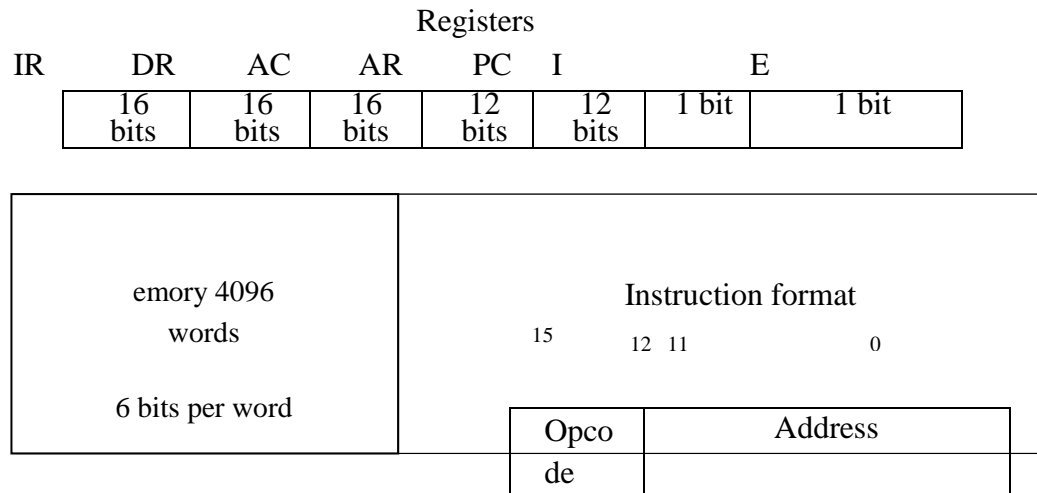
## Practical

(30 hours)

### List of Practicals:

(Use Simulator – CPU Sim 3.6.9 or any higher version for the implementation)

1. Create a machine based on the following architecture:



### Basic Computer Instructions

Memory Reference			Register Reference	
Symbol	Hex		Symbol	Hex
AND	0xxx	Direct Addressing	CLA	7800
ADD	1xxx		CLE	7400
LDA	2xxx		CMA	7200
STA	3xxx		CME	7100
BUN	4xxx		CIR	7080
BSA	5xxx		CIL	7040
ISZ	6xxx		INC	7020
AND_I	8xxx	Indirect Addressing	SPA	7010
ADD_I	9xxx		SNA	7008
LDA_I	Axxx		SZA	7004
STA_I	Bxxx		SZE	7002
BUN_I	Cxxx		HLT	7001
BSA_I	Dxxx		INP	F800
ISZ_I	Exxx		OUT	F400

Refer to Chapter-5 of reference 1 for description of instructions.

Design the register set, memory and the instruction set. Use this machine for the assignments of this section.

2. Create a Fetch routine of the instruction cycle.
3. Write an assembly program to simulate ADD operation on two user-entered numbers.
4. Write an assembly program to simulate SUBTRACT operation on two user-entered numbers.
5. Write an assembly program to simulate the following logical operations on two user-entered numbers.
  - i. AND
  - ii. OR
  - iii. NOT
  - iv. XOR
  - v. NOR
  - vi. NAND
6. Write an assembly program for simulating following memory-reference instructions.
  - i. ADD
  - ii. LDA
  - iii. STA
  - iv. BUN
  - v. ISZ
7. Write an assembly language program to simulate the machine for following register reference instructions and determine the contents of AC, E, PC, AR and IR registers in decimal after the execution:
  - i. CLA
  - ii. CMA
  - iii. CME
  - iv. HLT
8. Write an assembly language program to simulate the machine for following register reference instructions and determine the contents of AC, E, PC, AR and IR registers in decimal after the execution:
  - i. INC



- ii. SPA
  - iii. SNA
  - iv. SZE
9. Write an assembly language program to simulate the machine for following register reference instructions and determine the contents of AC, E, PC, AR and IR registers in decimal after the execution:
- i. CIR
  - ii. CIL
10. Write an assembly program that reads in integers and adds them together; until a negative non-zero number is read in. Then it outputs the sum (not including the last number).
11. Write an assembly program that reads in integers and adds them together; until zero is read in. Then it outputs the sum.

### **Essential Readings**

- David A. Patterson and John L. Hennessy. “Computer Organization and Design: The Hardware/Software interface”, 5th edition, Elsevier, 2012.
- Mano, M. Computer System Architecture, 3rd edition, Pearson Education, 1993.

### **Suggestive Readings**

- Mano, M. Digital Design, Pearson Education Asia, 1995.
- Null, L., & Lobur, J. The Essentials of Computer Organization and Architecture. 5th edition, (Reprint) Jones and Bartlett Learning, 2018.
- Stallings, W. Computer Organization and Architecture Designing for Performance 8th edition, Prentice Hall of India, 2010.

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## DISCIPLINE SPECIFIC CORE COURSE – 3: MATHEMATICS 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		
Mathematics for Computing	4	3	0	1	Class XII pass	NIL

#### Learning Objectives

The Learning Objectives of this course are as follows:

- Introduces the students to the fundamental concepts and topics of linear algebra and vector calculus.
- To build the foundation for some of the core courses in later semesters.

#### Learning Outcomes

This course will enable the students to:

- Perform operations on matrices and sparse matrices.
- Compute the determinant, rank and eigenvalues of a matrix.
- Perform diagonalization.
- Perform operations on vectors, the dot product and cross product.
- Represent vectors geometrically and calculate the gradient, divergence, curl.
- Apply linear algebra and vector calculus to solve problems in sub-disciplines of computer science.

### SYLLABUS OF DSC – 3

#### Theory

#### Unit – 1 (6 hours)

##### Introduction to Matrix Algebra

Echelon form of a Matrix, Rank of a Matrix, Determinant and Inverse of a matrix, Solution of System of Homogeneous & Non-Homogeneous Equations: Gauss elimination and Solution of System of Homogeneous Equations: Gauss Jordan Method.

#### Unit – 2 (21 hours)

##### Vector Space and Linear Transformation

Vector Space, Sub-spaces, Linear Combinations, Linear Span, Convex Sets, Linear Independence/Dependence, Basis & Dimension, Linear transformation on finite dimensional vector spaces, Inner Product Space, Schwarz Inequality, Orthonormal Basis, Gram-Schmidt Orthogonalization Process.

### **Unit – 3**

**(9 hours)**

#### **EigenValue and EigenVector**

Characteristic Polynomial, Cayley Hamilton Theorem, Eigen Value and Eigen Vector of a matrix, Eigenspaces, Diagonalization, Positive Definite Matrices, Applications to Markov Matrices.

### **Unit – 4**

**(9 hours)**

#### **Vector Calculus**

Vector Algebra, Laws of Vector Algebra, Dot Product, Cross Product, Vector and Scalar Fields, Ordinary Derivative of Vectors, Space Curves, Partial Derivatives, Del Operator, Gradient of a Scalar Field, Directional Derivative, Gradient of Matrices, Divergence of a Vector Field, Laplacian Operator, Curl of a Vector Field.

### **Practical**

**(30 hours)**

#### **List of Practicals:**

1. Create and transform vectors and matrices (the transpose vector (matrix) conjugate transpose of a vector (matrix))
2. Generate the matrix into echelon form and find its rank.
3. Find cofactors, determinant, adjoint and inverse of a matrix.
4. Solve a system of Homogeneous and non-homogeneous equations using Gauss elimination method.
5. Solve a system of Homogeneous equations using the Gauss Jordan method.
6. Generate basis of column space, null space, row space and left null space of a matrix space.
7. Check the linear dependence of vectors. Generate a linear combination of given vectors of  $R^n$ / matrices of the same size and find the transition matrix of given matrix space.
8. Find the orthonormal basis of a given vector space using the Gram-Schmidt orthogonalization process.
9. Check the diagonalizable property of matrices and find the corresponding eigenvalue and verify the Cayley- Hamilton theorem.
10. Application of Linear algebra: Coding and decoding of messages using nonsingular matrices.  
eg code “Linear Algebra is fun” and then decode it.
11. Compute Gradient of a scalar field.
12. Compute Divergence of a vector field.
13. Compute Curl of a vector field.

#### **Essential Reading**

- Strang Gilbert. Introduction to Linear Algebra, 5th Edition, Wellesley-Cambridge Press, 2021.
- Kreyszig Erwin. Advanced Engineering Mathematics, 10th Edition, Wiley, 2015.

- Strang Gilbert. Linear Algebra and Learning from Data, 1st Edition, Wellesley-Cambridge Press, 2019.
- Jain R. K., Iyengar S.R. K. Advanced Engineering Mathematics, 5th Edition, Narosa, 2016.

### **Suggestive Reading**

- Deisenroth, Marc Peter, Faisal A. Aldo and Ong Cheng Soon. Mathematics for Machine Learning, 1st Edition, Cambridge University Press, 2020.
- (Lipschutz Seymour and Lipson Marc. Schaum's Outline of Linear Algebra, 6th Edition, McGraw Hill, 2017.

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

## B.Sc. (H) with Computer Science as Major

### CATEGORY-II

#### DISCIPLINE SPECIFIC CORE COURSE – 1: INTRODUCTION TO PROGRAMMING 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		
Introduction to Programming using C++	4	3	0	1	Class XII pass	Nil

#### Learning Objectives

This course is designed to:

- Introduce programming concepts using C++ to students.
- Develop structured as well as object-oriented programming skills using C++ programming language.
- Achieve competence amongst its students to develop correct and efficient C++ programs to solve problems spanning multiple disciplines.

#### 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++.
- Solve problems spanning multiple disciplines using suitable programming constructs in C++.
- Solve problems spanning multiple disciplines using the concepts of object oriented programming in C++.

#### SYLLABUS OF DSC - 1

##### Theory

##### Unit – 1

(3 hours)

##### Introduction to C++

Need and characteristics of Object-Oriented Programming, Structure of a C++ Program (main () function, header files, output, input, comments), compile and execute a simple program

**Unit – 2** (9 hours)

**Data types and Expressions**

Keywords, built in data types, variables and constants, naming convention, Input-Output statements, operators and their precedence, expressions, typecasting, library functions

**Unit – 3** (12 hours)

**Control Constructs in C++**

Decision making using selection constructs, iteration using looping constructs.

**Unit – 4** (6 hours)

**Arrays, Pointers and User Defined Functions**

Defining and initializing single and multi-dimensional arrays, user defined functions, passing arguments to functions, returning values from functions, inline functions, default arguments, introduction to pointers

**Unit – 5** (15 hours)

**Classes and Objects**

Need and implementation of abstraction, encapsulation, inheritance and polymorphism, creating classes, objects as function arguments, modifiers and access control, constructors and destructors.

**Practical** (30 hours)

**List of Practicals:**

1. Write a program to find the largest of n natural numbers.
2. Write a program to find whether a given number is prime or not.
3. Write a program that takes a positive integer n and the produce n lines of output as shown:  
\*  
  
\* \*  
  
\* \* \*  
  
\* \* \* \*  
  
(for n = 4)
4. Write a menu driven program for following:
  - a. to check whether a given number is odd or even.
  - b. display a fibonacci series
  - c. compute factorial of a number
5. Write a program to accept a number, reverse it and print the sum of its digits.
6. Write a program using functions to print the series and its sum:  
 $1 + 1/2! + 1/3! + \dots + 1/n!$
7. Write a program to perform the following operations on an input string

- a. Print length of the string
  - b. Find frequency of a character in the string
  - c. Print whether characters are in uppercase or lowercase
  - d. to check whether a given string is palindrome or not.
8. Write a program that will prompt the user for a list of 5 prices. Compute the average of the prices and find out all the prices that are higher than the calculated average.
9. Design a class named Vehicle, having registration number and year as its private members. Define a suitable constructor and a method to print the details of a vehicle. Write a C++ program to test the above class.
10. Inherit a class Car from the Vehicle class defined above. Add model to the Car class. Define a suitable constructor and a method to print the details of a car. Write a C++ program to test inheritance of this class.

### Essential Readings

- E. Balaguruswamy, Object Oriented Programming with C++, 7th edition, McGraw-Hill Education, 2017.
- 2. Robert Lafore, Object Oriented Programming in C++, 4th edition, SAMS Publishing, 2008.

### Suggestive Reading

- D.S. Malik, C++ Programming: From Problem Analysis to Program Design, 6th edition, Cengage Learning, 2013.
- (ii) Herbert Schildt, C++: The Complete Reference, 4th Edition, McGraw Hill, 2003.

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

## DISCIPLINE SPECIFIC CORE COURSE – 2: PROGRAMMING FUNDAMENTALS 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		
Programming Fundamentals Using Python	4	3	0	1	Class XII pass	Nil

### Learning Objectives

This course is designed to:

- Introduce programming concepts using Python to students.
- Develop structured as well as object-oriented programming skills using Python.
- Achieve competence amongst its students to develop correct and efficient Python programs to solve problems spanning multiple disciplines.

### Learning Outcomes

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

- Write simple programs using built-in data types of Python.
- Implement arrays and user defined functions in Python.
- Solve problems spanning multiple disciplines using suitable programming constructs in Python.
- Solve problems spanning multiple disciplines using the concepts of object-oriented programming in Python.

## SYLLABUS OF DSC - 2

### Theory

#### Unit – 1 (6 hours)

##### Introduction to Python Programming

Problem solving strategies; Structure of a Python program; Syntax and semantics; Python interpreter/shell, indentation; Executing simple programs in Python.

#### Unit – 2 (12 hours)

##### Creating Python Programs

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), Errors and exception handling.

#### Unit – 3 (9 hours)

##### User Defined Functions

Defining functions, passing arguments and returning values, default arguments

#### Unit – 4 (18 hours)

##### Built-in Data Structures

Strings, Lists, Tuples, Sets, Dictionaries; their built-in functions, operators and operations

#### Practical (30 hours)

##### List of Practicals:

1. WAP to calculate total marks, percentage and grade of a student. Marks obtained in each of three subjects are to be input by the user. Assign grades according to the following criteria:

Grade A : if Percentage  $\geq 80$



Grade B : if Percentage  $\geq 60$  and Percentage  $< 80$

Grade C : if Percentage  $\geq 40$  and Percentage  $< 60$

Grade D : if Percentage  $\leq 40$

2. WAP to print factors of a given number.
3. WAP to add N natural numbers and display their sum.
4. WAP to print the following conversion table (use looping constructs):

Height (in Feet)	Height (in inches)
5.0 ft	60 inches
5.1 ft	61.2 inches
5.8 ft	69.6 inches
5.9 ft	70.8 inches
6.0 ft	72 inches

5. WAP that takes a positive integer n and the produce n lines of output as shown:

```
*
* *
* * *
* * * *
```

(for n =4)

6. Write a menu driven program using user defined functions to print the area of rectangle, square, circle and triangle by accepting suitable input from user.
7. Write a function that calculates factorial of a number n.
8. WAP to print the series and its sum: (use functions)  
 $1/1! + 1/2! + 1/3! + \dots + 1/n!$
9. WAP to perform the following operations on an input string
  - a. Print length of the string
  - b. Find frequency of a character in the string
  - c. Print whether characters are in uppercase or lowercase
10. WAP to create two lists: one of even numbers and another of odd numbers. The program should demonstrate the various operations and methods on lists.
11. WAP to create a dictionary where keys are numbers between 1 and 5 and the values are the cubes of the keys.
12. WAP to create a tuple  $t1 = (1,2,5,7,2,4)$ . The program should perform the following:
  - a. Print tuple in two lines, line 1 containing the first half of tuple and second line having the second half.

- b. Concatenate tuple  $t_2 = (10,11)$  with  $t_1$ .

### **Essential Readings**

- Kamthane, A. N., & Kamthane, A.A. Programming and Problem Solving with Python, McGraw Hill Education, 2017.
- Balaguruswamy E. “Introduction to Computing and Problem Solving using Python”, 2nd edition, McGraw Hill Education, 2018.
- Taneja, S., Kumar, N. Python Programming- A modular Approach, Pearson Education India, 2018.

### **Suggestive Readings**

- Guttag, J. V. Introduction to computation and programming using Python, MIT Press, 2018.
- (ii) Downey, A. B. Think Python—How to think like a Computer Scientist 2nd edition. O'Reilly 2015.

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

## B.Sc. (H) with Computer Science as Minor

### CATEGORY-III

#### DISCIPLINE SPECIFIC CORE COURSE: PROGRAMMING FUNDAMENTALS 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		
Programming fundamentals using C++	4	3	0	1	Class XII pass	Nil

#### Learning Objectives

The Learning Objectives of this course are as follows:

- Introduce programming concepts using C++ to students.
- Develop structured as well as object-oriented programming skills using C++ programming language.
- Achieve competence amongst its students to develop correct and efficient C++ programs to solve problems spanning multiple domains.

#### Learning outcomes

This course will enable the students 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

##### Theory

##### Unit – 1

(3 hours)

##### Introduction to C++

Need and characteristics of Object-Oriented Programming, Structure of a C++ Program (main () function, header files, output, input, comments), compile and execute a simple program

**Unit – 2 (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 – 3 (9 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 – 4 (9 hours)**

**Pointers and References**

Static and dynamic memory allocation, Pointer and Reference Variables, Implementing Runtime polymorphism using pointers and references.

**Unit – 5 (12 hours)**

**Exception and File Handling**

Using try, catch, throw, throws and finally; Nested try, File I/O Basics, File Operations

**Practical (30 hours)**

**List of Practicals:**

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

$$S = 1 - 2^n + 3^n - 4^n + \dots$$

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 display the following pattern:

A  
BA  
CBA  
DCBA

The number of rows n, is to be taken from the user.

3. Write a program to compute the factors of a given number using the default argument.

4. Write a menu driven program to perform the following operations on an array:
  - a. Find the minimum, maximum and average of the array elements
  - b. Search an element in the array using linear search
  - c. Search an element in the array using binary search (both iterative and recursive versions)
  - d. Display the address of every element of the array
5. Write a menu driven program to perform the following operations on a string:
  - a. Calculate length of the string (use pointers)
  - b. Check whether the first character of every word in the string is in uppercase or not
  - c. Reverse the string
  - d. Display the address of every character in the string
6. Create a class Triangle. Include overloaded functions for calculating the area of a triangle.
7. Create a template class TwoDim which contains x and y coordinates. Define default constructor, parameterized constructor and void print() function to print the coordinates. Now reuse this class in ThreeDim adding a new dimension as z. Define the constructors and void print() in the subclass. Implement main() to show runtime polymorphism.
8. Copy the contents of one text file to another file and display the number of characters copied.

### Essential Readings

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

### Suggestive Readings

- Herbert Schildt, C++: The Complete Reference, 4th Edition, McGraw Hill, 2003.
- A. B. Forouzan, Richard F. Gilberg, 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.

## LIST OF COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY DEPARTMENT OF COMPUTER SCIENCE

### CATEGORY-IV

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

##### GENERIC ELECTIVES: PROGRAMMING USING C++

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

#### Learning Objectives

The Learning Objectives of this course are as follows:

- Introduce programming concepts using C++ to students.
- Develop structured as well as object-oriented programming skills using C++ programming language.
- Achieve competence amongst its students to develop correct and efficient C++ programs to solve problems in their respective domains

#### Learning Outcomes

Upon completion of this course, students will be able to:

- Write simple programs using built-in data types of C++.
- Implement arrays and user defined functions in C++.
- Solve problems in the respective domain using suitable programming constructs in C++.
- Solve problems in the respective domain using the concepts of object oriented programming in C++.

#### SYLLABUS OF GE

##### Theory

##### Unit – 1

##### Introduction to C++

(9 hours)

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

**Unit – 2 (15 hours)**

**Programming Fundamentals**

Data types, Variables, Operators, Expressions, Arrays, Keywords, Decision making constructs, Iteration, Type Casting, Input-output statements, Functions

**Unit – 3 (21 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

**Practical (30 hours)**

**List of Practicals:**

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

$$S = 1 - 2 + 3 - 4 + \dots n$$

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 display the following pattern:

```
1
22
333
4444
55555
```

The number of rows n, is to be taken from the user.

3. Write a program to compute the factors of a given number.
4. Write a menu driven program to perform the following operations on an array:
  - a. Find the minimum, maximum and average of the array elements
  - b. Search an element in the array using linear and binary search
5. Write a menu driven program to perform the following operations on a string:

- a. Calculate length of the string
  - b. Check whether the first character of every word in the string is in uppercase or not
  - c. Reverse the string
6. Create a class Triangle. Include overloaded functions for calculating the area of a triangle.
7. Create a template class TwoDim which contains x and y coordinates. Define default constructor, parameterized constructor and void print() function to print the co-ordinates. Now reuse this class in ThreeDim adding a new dimension as z. Define the constructors and void print() in the subclass. Implement main() to show runtime polymorphism.

### Essential Readings

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

### Suggestive Reading

- Herbert Schildt, C++: The Complete Reference, 4th edition, McGraw Hill, 2003.
- A. B. Forouzan, Richard F. Gilberg, Computer Science: A Structured Approach using C++, 2nd edition, Cengage Learning, 2010.

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## GENERIC ELECTIVES: PROGRAMMING WITH 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		
Programming with Python  Code:	4	3	0	1	Class XII pass	NIL

### Learning Objectives

The Learning Objectives of this course are as follows:

- Introduce programming concepts using Python to students.



- Develop structured as well as object-oriented programming skills using Python.
- Achieve competence amongst its students to develop correct and efficient Python programs to solve problems in their respective domains.

### Learning outcomes

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

- Write simple programs using built-in data structures in Python.
- Implement arrays and user defined functions in Python.
- Solve problems in the respective domain using suitable programming constructs in Python.
- Solve problems in the respective domain using the concepts of object oriented programming in Python.

## SYLLABUS OF GE

### Theory

#### Unit - 1 (6 hours)

##### Introduction to Programming

Problem solving strategies; Structure of a Python program; Syntax and semantics; Executing simple programs in Python.

#### Unit - 2 (15 hours)

##### Creating Python Programs

Identifiers and keywords; Literals, numbers, and strings; Operators; Expressions; Input/output statements; Defining functions; Control structures (conditional statements, loop control statements, break, continue and pass, exit function), default arguments.

#### Unit - 3 (15 hours)

##### Built-in Data Structures

Mutable and immutable objects; Strings, built-in functions for string, string traversal, string operators and operations; Lists creation, traversal, slicing and splitting operations, passing list to a function; Tuples, sets, dictionaries and their operations.

#### Unit - 4 (9 hours)

##### File and Exception Handling

File handling through libraries; Errors and exception handling.

#### Practical (30 hours)

##### List of Practicals:

1. WAP to find the roots of a quadratic equation.
2. WAP to accept a number 'n' and
  - a. Check if 'n' is prime

- b. Generate all prime numbers till 'n'
  - c. Generate first 'n' prime numbers
  - d. This program may be done using functions.
3. WAP to create a pyramid of the character '\*' and a reverse pyramid

```

      *
     ***
    *****
   ********
  **********
 
```

```

          *****
         *****
        *****
       *****
      *****
     *****
    *****
   *****
  *****
 *****

```

4. WAP that accepts a character and performs the following:
  - a. print whether the character is a letter or numeric digit or a special character
  - b. if the character is a letter, print whether the letter is uppercase or lowercase
  - c. if the character is a numeric digit, prints its name in text (e.g., if input is 9, output is NINE)
5. WAP to perform the following operations on a string
  - a. Find the frequency of a character in a string.
  - b. Replace a character by another character in a string.
  - c. Remove the first occurrence of a character from a string.
  - d. Remove all occurrences of a character from a string.
6. WAP to swap the first n characters of two strings.
7. Write a function that accepts two strings and returns the indices of all the occurrences of the second string in the first string as a list. If the second string is not present in the first string then it should return -1.
8. WAP to create a list of the cubes of only the even integers appearing in the input list (may have elements of other types also) using the following:
  - a. 'for' loop
  - b. list comprehension

9. WAP to read a file and
- Print the total number of characters, words and lines in the file.
  - Calculate the frequency of each character in the file. Use a variable of dictionary type to maintain the count.
  - Print the words in reverse order.
  - Copy even lines of the file to a file named 'File1' and odd lines to another file named 'File2'.
10. Write a function that prints a dictionary where the keys are numbers between 1 and 5 and the values are cubes of the keys.
11. Consider a tuple t1=(1, 2, 5, 7, 9, 2, 4, 6, 8, 10). WAP to perform following operations:
- Print half the values of the tuple in one line and the other half in the next line.
  - Print another tuple whose values are even numbers in the given tuple.
  - Concatenate a tuple t2=(11,13,15) with t1.
  - Return maximum and minimum value from this tuple
12. WAP to accept a name from a user. Raise and handle appropriate exception(s) if the text entered by the user contains digits and/or special characters.

### Essential Readings

- Taneja, S., Kumar, N., Python Programming- A modular Approach, Pearson Education India, 2018.
- Balaguruswamy E., Introduction to Computing and Problem Solving using Python, 2nd edition, McGraw Hill Education, 2018.

### Suggestive Reading

- Brown, Martin C., Python: The Complete Reference, 2nd edition, McGraw Hill Education, 2018.
- Gutttag, J.V. Introduction to computation and programming using Python, 2nd edition, MIT Press, 2016.

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

## DEPARTMENT OF OPERATIONAL RESEARCH

### B.Sc. (H) Operational Research

#### Category-I

#### DISCIPLINE SPECIFIC CORE COURSE - 1: INTRODUCTION TO OPERATIONAL RESEARCH AND 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		
Introduction to Operational Research and Linear Programming	4	3	0	1	Class XII pass with Mathematics	Nil

#### Learning Objectives

The Learning Objective of the course is to introduce:

- Basic concepts of Operational Research and Linear Programming to the students.

#### Learning Outcomes:

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

- Gain an understanding of key concepts of Operational Research and Linear Programming and their role in various organizations.
- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
- Implement advanced and more economic algorithm to solve linear programming problems.

#### SYLLABUS OF DSC-1

##### Theory

##### Unit – 1

(9 hours)

**Basics of Operational Research:** Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Formulation of Real-Life Problems.

**Unit – 2 (15 hours)**

Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method. Concepts of Basis and Basic Feasible solution. Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Unit – 3 (9 hours)**

Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Unit – 4 (12 hours)**

Degeneracy in Linear Programming, Charnes' Perturbation method, Revised Simplex method.

**Practical**

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

1. To solve Linear Programming Problem (LPP) using Graphical Method with
  - (i) Unbounded solution.
  - (ii) Infeasible solution.
  - (iii) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M method.
4. Problem solving using Two Phase method.
5. Illustration of following special cases in LPP using Simplex method
  - (i) Unrestricted variables.
  - (ii) Unbounded solution.
  - (iii) Infeasible solution.
  - (iv) Alternative or multiple solutions.
6. Solution to linear programming problem through revised simplex method.

**Essential Readings**

- Hadley, G. (2002). Linear programming. New Delhi: Narosa Publishing House.
- Hadley, G. (2002). Linear Algebra. New Delhi: Narosa Publishing House.
- Hillier, F.S., & Lieberman, G. J. (2010). Introduction to operations research- concepts and cases (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
- Taha, H. A. (2017). Operations research - An Introduction (10th ed.). Pearson Education.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2005). Operations research- principles and practice (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).

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

## DISCIPLINE SPECIFIC CORE COURSE - 2: LINEAR ALGEBRA AND 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		
Linear Algebra and Calculus	4	3	1	0	Class XII pass with Mathematics	NIL

### Learning Objectives

The Learning Objectives of the course is to provide a platform for:

- Introduction to linear algebra and calculus.
- Providing the rudimentary idea of Mathematics to be useful in the course of Operational Research.

### Learning Outcomes

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

- Gain an understanding of key concepts of Linear Algebra and Calculus and their role in Operations Research.
- Describe the basic concepts of matrices and system of linear equations.
- Demonstrate the understanding of linear combinations, Linear span, Basis and Eigen values and related theorems.
- Explain the fundamentals of Limit, Continuity and Differentiability.
- Demonstrate the utility of Maxima, Minima and Lagrangian function.

## SYLLABUS OF DSC - 2

### Theory

#### Unit – 1 (16 hours)

**Matrices & System of Linear Equations:** Matrix Algebra, Types of Matrices, Elementary row operations on a Matrix, Echelon form of a Matrix, Rank of a Matrix, Inverse of a matrix, Solution of System of Homogeneous & Non-Homogeneous Equations.

#### Unit – 2 (16 hours)

**Vector Spaces:** Definition, Sub-spaces, Linear Combinations, Linear independence and dependence of vectors, Linear Span, Basis & Dimension, Eigen Values, Eigen Vectors, Characteristic Polynomial, Diagonalization, Cayley Hamilton Theorem.

**Unit – 3** (16 hours)

**Calculus:** Functions of one variable: Limit, continuity, Differentiability, Intermediate value theorem, Rolle's Theorem, Mean value theorem, Cauchy's mean value theorem, Taylor series, Maclaurin series.

**Unit – 4** (12 hours)

Concepts of Maxima and Minima, Lagrangian function and its geometric interpretation.

**Practical component (if any) – NIL**

**Essential Readings**

- Lay, D. C. (2015). Linear Algebra and its Applications (5th ed.). Pearson.
- Lang, S. (2004). Linear Algebra (3rd ed.). Springer.
- George, B. T. Jr. and Finney, R. L. (2010). Calculus and Analytic Geometry (9th ed.). Pearson.
- Strang, G. (2016). Introduction to Linear Algebra (5th ed.). Wellesey-Cambridge Press.

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

**DISCIPLINE SPECIFIC CORE COURSE - 3: 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
Production and Inventory Management	4	3	0	1	Class XII pass with Mathematics	NIL

**Learning Objectives**

The Learning Objectives of this course is to:

- Introduce fundamental concepts in production and inventory management.
- 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 DSC – 3**

#### **Theory**

##### **Unit – 1 (9 hours)**

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

##### **Unit – 2 (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 – 3 (9 hours)**

**Probabilistic inventory models:** Single period probabilistic inventory models with discrete and continuous demand.

##### **Unit – 4 (12 hours)**

Introduction to Production Planning and Scheduling, Aggregate production plan, Formulation of lot size production problem: Wagner and Whitin algorithm. Basic concepts of Just-in-Time (JIT) and Material Requirement Planning (MRP).

##### **Practical (30 hours)**

##### **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 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.
- 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.
- Waters, D. (2008). Inventory control and management. (2nd ed.). John Wiley & Sons.

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

**B.Sc. (Prog.) with Operational Research as Major**  
**Category II**

**DISCIPLINE SPECIFIC CORE COURSE – 1: INTRODUCTION TO OPERATIONAL  
RESEARCH AND 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		
Introduction to Operational Research and Linear Programming	4	3	0	1	Class XII pass with Mathematics	Nil

**Learning Objectives**

The Learning Objective of the course is to introduce:

- Basic concepts of Operational Research and Linear Programming to the students.

**Learning Outcomes:**

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

- Gain an understanding of key concepts of Operational Research and Linear Programming and their role in various organizations.
- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
- Implement advanced and more economic algorithm to solve linear programming problems.

**SYLLABUS OF DSC-1**

**Theory**

**Unit – 1**

**(9 hours)**

**Basics of Operational Research:** Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational

Research Study, Scope and Limitations of Operational Research, Mathematical Formulation of Real-Life Problems.

**Unit – 2 (15 hours)**

Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method. Concepts of Basis and Basic Feasible solution. Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Unit – 3 (9 hours)**

Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Unit – 4 (12 hours)**

Degeneracy in Linear Programming, Charnes' Perturbation method, Revised Simplex method.

**Practical**

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

1. To solve Linear Programming Problem (LPP) using Graphical Method with
  - (i) Unbounded solution.
  - (ii) Infeasible solution.
  - (iii) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M method.
4. Problem solving using Two Phase method.
5. Illustration of following special cases in LPP using Simplex method
  - (i) Unrestricted variables.
  - (ii) Unbounded solution.
  - (iii) Infeasible solution.
  - (iv) Alternative or multiple solutions.
6. Solution to linear programming problem through revised simplex method.

**Essential Readings**

- Hadley, G. (2002). Linear programming. New Delhi: Narosa Publishing House.
- Hadley, G. (2002). Linear Algebra. New Delhi: Narosa Publishing House.
- Hillier, F.S., & Lieberman, G. J. (2010). Introduction to operations research- concepts and cases (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
- Taha, H. A. (2017). Operations research - An Introduction (10th ed.). Pearson Education.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2005). Operations research- principles and practice (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).

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

## DISCIPLINE SPECIFIC CORE COURSE - 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 (if any)
		Lecture	Tutorial	Practical/ Practice		
Production and Inventory Management	4	3	0	1	Class XII pass with Mathematics	NIL

### Learning Objectives

The Learning Objectives of this course is to:

- Introduce fundamental concepts in production and inventory management.
- 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 DSC – 2

### Theory

#### Unit – 1

**(9 hours)**

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

#### Unit – 2

**(21 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 – 3**

**(6 hours)**

**Probabilistic inventory models:** Single period probabilistic inventory models with discrete and continuous demand.

### **Unit – 4**

**(9 hours)**

Introduction to Production Planning and Scheduling, Aggregate production plan, Formulation of lot size production problem: Wagner and Whitin algorithm. Basic concepts of Just-in-Time (JIT) and Material Requirement Planning (MRP).

### **Practical – 30 Hours**

#### **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 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.
- 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.
- Waters, D. (2008). Inventory control and management. (2nd ed.). John Wiley & Sons.

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

## B.Sc. (Prog.) with Operational Research as Minor

### *Category III*

#### DISCIPLINE SPECIFIC CORE COURSE - 1: INTRODUCTION TO OPERATIONAL RESEARCH AND 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		
Introduction to Operational Research and Linear Programming	4	3	0	1	Class XII pass with Mathematics	Nil

#### Learning Objectives

The Learning Objective of the course is to introduce:

- Basic concepts of Operational Research and Linear Programming to the students.

#### Learning Outcomes:

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

- Gain an understanding of key concepts of Operational Research and Linear Programming and their role in various organizations.
- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
- Implement advanced and more economic algorithm to solve linear programming problems.

#### SYLLABUS OF DSC-1

##### Theory

##### Unit – 1

(9 hours)

**Basics of Operational Research:** Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Formulation of Real-Life Problems.

**Unit – 2 (15 hours)**

Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method. Concepts of Basis and Basic Feasible solution. Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

**Unit – 3 (9 hours)**

Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

**Unit – 4 (12 hours)**

Degeneracy in Linear Programming, Charnes' Perturbation method, Revised Simplex method.

**Practical (30 hours)**

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

1. To solve Linear Programming Problem (LPP) using Graphical Method with
  - (i) Unbounded solution.
  - (ii) Infeasible solution.
  - (iii) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M method.
4. Problem solving using Two Phase method.
5. Illustration of following special cases in LPP using Simplex method
  - (i) Unrestricted variables.
  - (ii) Unbounded solution.
  - (iii) Infeasible solution.
  - (iv) Alternative or multiple solutions.
6. Solution to linear programming problem through revised simplex method.

**Essential Readings**

- Hadley, G. (2002). Linear programming. New Delhi: Narosa Publishing House.
- Hadley, G. (2002). Linear Algebra. New Delhi: Narosa Publishing House.
- Hillier, F.S., & Lieberman, G. J. (2010). Introduction to operations research- concepts and cases (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
- Taha, H. A. (2017). Operations research - An Introduction (10th ed.). Pearson Education.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2005). Operations research- principles and practice (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).

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**COMMON POOL OF GENERIC ELECTIVES (GE) COURSES**  
**OFFERED BY DEPARTMENT OF OPERATIONAL RESEARCH**

*CATEGORY-IV*

**GENERIC ELECTIVES: INTRODUCTION TO OPERATIONAL  
RESEARCH AND 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		
Introduction to Operational Research and Linear Programming	4	3	0	1	Class XII pass with Mathematics	Nil

**Learning Objectives**

The Learning Objective of the course is to introduce:

- Basic concepts of Operational Research and Linear Programming to the students.

**Learning Outcomes:**

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

- Gain an understanding of key concepts of Operational Research and Linear Programming and their role in various organizations.
- Describe the basic concepts of convex analysis and explain the theoretical foundations of various issues related to linear programming modelling.
- Formulate real-world problems as a linear programming model and describe the theoretical workings of the graphical and simplex method, demonstrate the solution process by hand and solver.
- Implement advanced and more economic algorithm to solve linear programming problems.



## SYLLABUS OF GE

### Theory

#### Unit – 1 (9 hours)

**Basics of Operational Research:** Origin & Development of Operational Research, Definition and Meaning of Operational Research, Different Phases of an Operational Research Study, Scope and Limitations of Operational Research, Mathematical Formulation of Real-Life Problems.

#### Unit – 2 (15 hours)

Introduction to Linear Programming, Linear Programming Problem Formulation, Solution by Graphical Method. Concepts of Basis and Basic Feasible solution. Convex sets, Extreme points, Hyperplanes and Halfspaces, Convex cones, Polyhedral sets and cones.

#### Unit – 3 (9 hours)

Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charne's-M Method.

#### Unit – 4 (12 hours)

Degeneracy in Linear Programming, Charnes' Perturbation method, Revised Simplex method.

### Practical (30 hours)

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

1. To solve Linear Programming Problem (LPP) using Graphical Method with
  - (i) Unbounded solution.
  - (ii) Infeasible solution.
  - (iii) Alternative or multiple solutions.
2. Solution of LPP with simplex method.
3. Problem solving using Charnes-M method.
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5. Illustration of following special cases in LPP using Simplex method
  - (i) Unrestricted variables.
  - (ii) Unbounded solution.
  - (iii) Infeasible solution.
  - (iv) Alternative or multiple solutions.
6. Solution to linear programming problem through revised simplex method.

#### Essential Readings

- Hadley, G. (2002). Linear programming. New Delhi: Narosa Publishing House.
- Hadley, G. (2002). Linear Algebra. New Delhi: Narosa Publishing House.
- Hillier, F.S., & Lieberman, G. J. (2010). Introduction to operations research- concepts and cases (9th ed.). New Delhi: Tata McGraw Hill (Indian print).
- Taha, H. A. (2017). Operations research - An Introduction (10th ed.). Pearson Education.

- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2005). Operations research- principles and practice (2nd ed.). New Delhi: Wiley India (P.) Ltd. (Indian print).

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**REGISTRAR**