FOUR YEAR UNDERGRADUATE (FYUG) PROGRAMME UNDER NEW EDUCATION POLICY, 2020

# STATISTICS

**Date of approval in Academic Council -30th May and 21st June 2024**

# Preface

The four-year undergraduate (FYUG) syllabus for Statistics has been framed in accordance with NEP-2020 guidelines. As per NEP-2020 recommendations, the course has been designed keeping in view multiple exit options:

(i) A certificate after successful completion of one year of study;

(ii) A diploma after successful completion of two years of study;

(iii) A 3-year UG degree after successful completion of three years of study; and

(iv) A UG Honours or UG Honours with Research after successful completion of a four years of study.

The FYUG programme in Statistics has been designed to motivate and inspire students to develop a deep interest in the subject Statistics, develop problem-solving abilities and understand statistical theory, practical and statistical tools and softwares. It includes laboratory work and practical exercises that allow students to apply theoretical concepts to real-world problems and enhance their scientific skills. It also trains the students to use various statistical packages in analysing data, obtain estimates of necessary parameters, set and test hypotheses and draw meaningful inferences thereby preparing technically proficient statisticians. It also aims to provide students with necessary knowledge and skills to design a survey instrument, select a sample scientifically from the population under study, conduct survey to collect data, represent data in various forms, analyse collected data and draw valid conclusions that could be used in decision making. The programme includes a base of theoretical work complemented by practical analysis of real-world data to give them training in applying and sharpening the skills they have acquired during the course of the programme. The course aims to disseminate academic, research, and professional development knowledge to the students.

**Programme Outcomes:**

Upon completion of the programme, the learners will be able to:

- Plan for a scientific investigation for an identified issue.
- Design an appropriate instrument to be used for collection of data related to the identified issue.
- Select a representative sample from the population under study and administer survey to collect relevant data.
- Organize and present data in suitable form (diagrams, graphs, measures etc.).
- Handle and analyse large datasets with computer skills and use their results and interpretations to make practical suggestions for improved decision making.
- Apply statistical methods and modelling techniques to real-world problems in both observational and designed studies.
- Employ their knowledge and expertise for the development of a research enquiry and to select the tools necessary for executing the research
- Develop independent learning strategies.
- Coordinate and work with multidisciplinary teams.
- Display a capacity for logical thinking, structured reasoning and synthesis

# Structure of the Syllabus

**1st Semester**

| Course Code | Title of the Course | Credits | | | Total Contact hours |
|---|---|---|---|---|---|
| | | Theory | Practical | Total | |
| STA - 100 | Introductory Statistics | 3 | 1 | 4 | 75 |
| STA-100 | Introductory Statistics (Minor) | 3 | 1 | 4 | 75 |
| MDC-110.....119 | Any one of the available MDC Courses to be chosen | 3 | - | 3 | 45 |
| AEC-120….129 | Any one of the available AEC Courses to be chosen | 3 | - | 3 | 45 |
| SEC-130…...139 | Any one of the available SEC Courses to be chosen | | | 3 | 45-90 |
| VAC-140 | Any of the available course as notified by the University from time to time | 3 | - | 3 | 45 |
| | | | | **20** | |

**2nd Semester**

| Course Code | Title of the Course | Credits | | | Total Contact hours |
|---|---|---|---|---|---|
| | | Theory | Practical | Total | |
| STA – 150 | Introduction to Probability and Applied Statistics | 3 | 1 | 4 | 75 |
| STA-150 | Introduction to Probability and Applied Statistics | 3 | 1 | 4 | 75 |
| MDC – 161 | Fundamentals of Statistics | 2 | 1 | 3 | 60 |
| AEC-170…..179 | Any of the available course as notified by the University from time to time | 3 | - | 3 | 45 |
| SEC-180……189 | Any of the available course as notified by the University from time to time | | | 3 | 45-90 |
| VAC-190…...199 | Any of the available course as notified by the University from time to time | 3 | - | 3 | 45 |
| | | | | **20** | |

**3rd Semester**

| Course Code | Title of the Course | Credits | | | Total Contact hours |
|---|---|---|---|---|---|
| | | Theory | Practical | Total | |
| STA – 200 | Mathematical Analysis and Numerical Methods | 3 | 1 | 4 | 75 |
| STA – 201 | Probability Theory and Probability Distribution | 3 | 1 | 4 | 75 |
| MDC 210 to 219 | Any of the available course as notified by the University from time to time | 3 | - | 3 | 45 |
| AEC 220-229 | Any of the available course as notified by the University from time to time | 2 | - | 2 | 30 |
| SEC 230-239 | Any of the available course as notified by the University from time to time | | | 3 | 45-90 |
| VTC 240-249 | Any of the available course as notified by the University from time to time | 1 | 3 | 4 | 105 |

**4th Semester**

| Course Code | Title of the Course | Credits | | | Total Contact hours |
|---|---|---|---|---|---|
| | | Theory | Practical | Total | |
| STA - 250 | Distribution Theory | 3 | 1 | 4 | 75 |
| STA – 251 | Matrix and Linear Algebra | 3 | 1 | 4 | 75 |
| STA - 252 | Introduction to Statistical Inference | 3 | 1 | 4 | 75 |
| STA – 253 | Introduction to Sample Survey | 3 | 1 | 4 | 75 |
| VTC 260-269 | Any of the available course as notified by the University from time to time | 1 | 3 | 4 | 105 |

**5th Semester**

| Course Code | Title of the Course | Credits | | | Total Contact hours |
|---|---|---|---|---|---|
| | | Theory | Practical | Total | |
| STA – 300 | Introduction to Design of Experiments | 3 | 1 | 4 | 75 |
| STA – 301 | Testing of Hypothesis | 3 | 1 | 4 | 75 |
| STA – 302 | Applied Statistics | 3 | 1 | 4 | 75 |
| STA - 302 | Theory of Attributes, Categorical data and Demand analysis (Minor) | 3 | 1 | 4 | 75 |
| STA-303 | Internship/Apprenticeship/Community engagement and service field based learning or minor project | - | 4 | 4 | 120 |

6th Semester

| Course Code | Title of the Course | Credits | | | Total Contact hours |
|---|---|---|---|---|---|
| | | Theory | Practical | Total | |
| STA – 350 | Non – Parametric & Sequential Procedures | 3 | 1 | 4 | 75 |
| STA – 351 | Linear Estimation and Linear Models | 3 | 1 | 4 | 75 |
| STA – 352 | Regression Analysis | 3 | 1 | 4 | 75 |
| STA – 353 | Advanced Survey Sampling | 3 | 1 | 4 | 75 |
| VTC 360-369 | Any of the available course as notified by the University from time to time | 1 | 3 | 4 | 105 |

**Assessment Approach**

1. For papers having both of the theory as well as practical components, the assessment approach will be as follows:

| | Internal | End Semester |
|---|---|---|
| Theory ( Part A, 3 credits) | 19 | 56 |
| Theory (Part A, 2 credits) | 12 | 38 |
| Practical (Part B, 1 credit) | 6 | 19 |
| For VTC Courses | 40 | 60 |

* Students securing 75% marks or more in aggregate in 6 Semester are eligible to opt for Honours with Research.

# All others students must opt for UG Honours with 3 Advances Courses, viz STA-453, STA-454 and SUB-455 in lieu of STA-452.

## STA – 200: Mathematical Analysis and Numerical Methods

**75 Lecture Hours** **4 Credits**

**Course Objectives:** The objectives of this course typically revolve around equipping students with a solid understanding of fundamental concepts and techniques in calculus and providing students with the necessary skills and knowledge to solve mathematical problems using computational techniques.

**Learning Outcomes:** By the end of the course, students should be equipped with a strong foundation in calculus that prepares them for further studies in Statistics where calculus is applied and with the knowledge, skills, and tools necessary to apply numerical methods effectively in solving real-world problems and to prepare them for further study or professional practice in fields requiring computational expertise.

### Part – A (Theory)

**UNIT-I:**

Differential Calculus: Functions, Limit of a function. Derivatives, Rules of differentiation of sum, difference, product, quotient of function and function of functions. Integral Calculus: Integration as reverse of differentiation (Simple cases only), Method of substitution, Definite Integrals (Simple examples only). Function of several variables, partial derivatives, maxima and minima, constrained maxima and minima, Applications of Lagrange multipliers. Multiple integrals of Jacobian of transformation, Gamma and Beta integrals.

(15 hours)

**UNIT-II:**

Finite differences: Definition, Operators $\Delta, \nabla$ & E and their properties, difference table, methods of interpolation formulae - Newton's Forward and Backward interpolation, Lagrange's method of interpolation. Newton's divided difference interpolations.

Numerical Integration, Taylor series: General Quadrature formula – Trapezoidal rule, Simpson's one-third and three-eighth formulae.

(15 hours)

**UNIT-III:**

Numerical Differentiation: Concept, Numerical Differentiation using Newton's Forward and Backward Interpolation Formulae. Numerical Integration: Concept, Weddle's Rule and Euler-Maclaurin's Summation Formula and Integration. Solution of Algebraic and Transcendental equations by using methods of Bisection, False position, Iteration method, Newton Raphson with their convergence (polynomials up to degree 4).

(15 hours)

## Part – B (Practical)

### UNIT-IV: Practical

(30 hours)

Problem on interpolation using Newton's Forward & Backward interpolation formulae. Problem on interpolation using Lagrange's formulae. Problem on interpolation using divided difference formulae. Problem on Integration using Trapezoidal, Simpson's one-third & three-eighth formulae. Problem on first and second derivatives using Newton's forward & backward interpolation formulae. Problem on numerical integration using Weddle's rule and Euler's formulae. Problem on solving equations using methods of Bisection, False position (or Regula Falsi), Iteration and Newton-Raphson (up to fourth degree of polynomials).

### Suggested Readings:


1. Cheney, E. W., & Kincaid, D., (2008). Numerical Mathematics and Computing. 6th Edition, Thomson Brooks/Cole.
2. Das, B. C. and Mukherjee, B. N., 54th Edition, Differential Calculus, U.N. Dhur and Sons Pvt. Ltd.
3. Das, B. C. and Mukherjee, B. N., 55th Edition, Differential Calculus, U.N. Dhur and Sons Pvt. Ltd.
4. Faires, J. D., & Burden, R. L., (2012), Numerical analysis. 9th Edition, Cengage Learning, Inc.
5. Goon, A. M., Gupta, M. K. & Dasgupta, B. (2013), Fundamental of Statistics, Volume 1, World Press Kolkata.
6. Gupta, S. C. & Kapoor, V. K. (2014), Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.
7. Jain, M. K., Iyengar, S. R. K., Jain, R. K. (2020), Numerical Methods: Problems and Solutions, New Age International Publishers.
8. Maity & Ghosh. (1999), Integral Calculus, New Central Book Agency (P) Limited.
9. Maity & Ghosh. (2009), Differential Calculus, New Central Book Agency (P) Limited.
10. RajaRaman, V. (2018), Computer Oriented Numerical Methods. 4th Edition, PHI learning Private Limited, New Delhi.
11. Saxena, H. C. (2014), Calculus of Finite Differences, S. Chand & Co.
12. Thilagavathy, K. & Kandasamy, P., Calculus of Finite Differences and Numerical Analysis for B.Sc., S. Chand & Co.
13. Venkateswara, V. R., Sarma, B. V. S. S., Krishnamurthy, N., Anjaneya S. S., & Ranganathama, S. (2019), Textbook of B.Sc. Mathematics (Differential & Integral Calculus): Semester I, S. Chand & Co.

## STA – 201: Probability Theory and Probability Distribution

**75 Lecture Hours** **4 Credits**

**Course objectives:** The course aims to provide students with a comprehensive understanding of probability theory and probability distributions, their properties, and applications, and to enable them to develop a deep comprehension of sampling distribution theory.

**Learning outcomes:** By course completion, students should have a comprehensive understanding of probability theory and probability distributions, will be able to apply them to various situations, and possess the skills to interpret and communicate the results effectively. They will have an in-depth grasp of the fundamentals, characteristics, and practical applications of random variables. They should confidently apply sampling distribution theory in practical scenarios.

### Part – A (Theory)

**UNIT-I:**

Definition of probability: classical, axiomatic, and relative frequency approaches. Discrete sample space and its properties. Conditional probability and independence of events, addition, and multiplication theorems with proof. Bayes' theorem and its applications. Definition & Derivation of properties including mgf, pgf & cgf of (i) Bernoulli, (ii) Binomial, (iii) Poisson. Derivation of Mean, Variance and other properties and related problems.

(15 hours)

**UNIT-II:**

Definition & Derivation of properties including mgf, pgf & cgf of Normal distribution. Derivation of Mean, Variance and other properties and related problems. Ideas of box plot and stem and leaf plot, q-q plot, p-p plot. Random Sample from a Probability Distribution, Statistic and its sampling distribution. Distribution of functions of Random Variables.

(15 hours)

**UNIT-III:**

Distribution of sums of independent random variables, Distribution of Sample mean from Normal Population. Chi-Square, t- and F- distributions – definition, properties, and their derivation. Law of Large Numbers; Tschebyshev's Inequality and its Applications. Statement and application of Weak Law of Large Numbers (WLLN). Concept of Central Limit Theorem.

(15 hours)

## Part – B (Practical)

### UNIT-IV: Practical

(30 hours)

Problems based on Univariate Discrete Distributions: (i) Binomial (ii) Poisson
Problems based on Univariate Continuous Distribution: Normal
Construction of Box Plot and Stem and Leaf plot

### Suggested readings:


1. Agarwal, B. L. (2013), Basic Statistics, New Age International (P) Ltd.
2. Goon, A. M., Gupta, M. K. & Dasgupta, B. (1999), Fundamental of Statistics, Vol. I, World Press, Kolkata.
3. Goon, A.M., Gupta, M. K. & Dasgupta, B. (1999), Fundamental of Statistics, Volume 1, World Press Kolkata.
4. Gupta, S. C. & Kapoor, V. K. (2000), Fundamentals of Mathematical Statistics, Sultan Chand and Sons, ND.
5. Gupta, S. C. (2014), Fundamentals of Mathematical Statistics, Sultan Chand & Sons.
6. Gupta, S. C. (2016), Fundamentals of Statistics, Himalaya Publishing House.
7. Hogg, R. V. & Craig, A. T. (2002), Introduction to Mathematical Statistics, 5th Ed., Pearson Education, New Delhi.
8. Hogg, R. V. & Tanis, E. A. (2003), Probability and Statistical Inference, Pearson Education, New Delhi.
9. Krishnan, V. (2011), Statistics for Beginners, Atlantic.
10. McKean, J., Hogg, R. V. & Craig, A. T. (2014), Introduction to Mathematical Statistics, 7th Ed., Pearson.
11. Ramachandran, K. M. & Tsokos, C. P. (2009), Mathematical Statistics with Applications, Elsevier.
12. Singh, R. (2012), An Introduction to Probability & Probability Distributions, Books & Allied (P) Ltd., Kolkata.

## STA-250: Distribution Theory

**75 Lecture Hours** **4 Credits**

**Course objectives:** To provide students with an in-depth understanding of random variables and related concepts, a solid grasp of probability distributions, their properties, and applications, and to enable them to develop a deep comprehension of sampling distribution theory.

**Learning outcomes:** On completion of the course, the students should have a comprehensive understanding of random variable and its joint, marginal and conditional distribution, will be able to understand the distribution of sample statistic and possess the skills to interpret and communicate the results effectively. They will have an in-depth grasp of the fundamentals, characteristics, and practical applications of random variables.

### Part – A (Theory)

**UNIT-I:**

Random Variables (RVs): Joint, marginal, and conditional Distribution Functions and their properties. Mathematical expectation of random variable, Properties of expectation of sums of Random Variables, covariance, and Variance of sums. Conditional expectation, computation of expectations, and variances. Probability by conditioning, conditioning variance. Generating Functions - Joint Moment generating function (MGF), Cumulant Generating function (CGF), and Probability Generating Function (PGF) of RVs, their properties and application, characteristics function.

(15 hours)

**UNIT-II:**

Negative Binomial, Hypergeometric, Beta, Gamma, and Cauchy distributions with their properties and applications. Derivation and independence of Sampling distributions of sample mean and variance in random sampling from the normal population, sampling distribution of sample total for negative binomial, normal, and gamma distributions.

(15 hours)

**UNIT-III:**

Definition of order statistics. Derivation of the cumulative distribution function and probability density function of the $r^{th}$ order statistics based on uniform distribution only, joint probability density function of the $r^{th}$ and the $s^{th}$ order statistics ($r<s$), joint probability density functions of all n order statistics, distribution of maximum observation ($n^{th}$ order statistics) and minimum observation ($1^{st}$ order statistics) in case of uniform distribution, distribution of sample median and sample range.

(15 hours)

## Part – B (Practical)

### UNIT-IV: Practical

(30 hours)

Problem based on fitting of Negative Binomial, Hypergeometric and Multinomial Distributions. Problem based on fitting of Gamma, Beta and Cauchy distributions.

### Suggested Readings:


1. Casella, George., Berger, Roger L. (2010), Statistical Inference, 2nd Edition. Cengage Learning India Pvt Ltd.
2. David, H.A. (1970), Order Statistics, John Wiley.
3. Goon, A.M., Gupta, M.K. and Dasgupta, B., (2002), Fundamentals of Statistics, Vol. I& II, 8th Edition. The World Press, Kolkata.
4. Gupta, S. C., & Kapoor, V. K. (2002), Fundamental of Mathematical Statistics. Sultan Chand & Sons.
5. Hogg, R. V. & Craig, A. T. (2002), Introduction to Mathematical Statistics, 5th Edition, Pearson & Education, ND.
6. Miller, Irwin., Miller, Marylees. (2006), John E Freund's Mathematical Statistics with Applications, 8th Edition. Pearson Education India, New Delhi
7. Rohatgi, VK., Saleh., AK Md E. (2015), An Introduction to Probability and Statistics. John Wiley & Sons. New Delhi.
8. Singh, R. (2012), An Introduction to Probability & Probability Distributions, Books & Allied (P) Ltd., Kolkata.

## STA – 251: Matrix and Linear Algebra

**75 Lecture Hours** **4 Credits**

**Course Objectives**: The objective of this course is that students will learn the fundamental concepts of matrix and linear algebra, to solve systems of linear equations and their applications in statistics

**Learning Outcomes:** After completing this course, students will demonstrate an understanding of fundamental concepts of matrix and linear algebra, application of matrix and linear algebra techniques in Statistics

### Part – A (Theory)

**UNIT-I:**

Matrices over R/C: Transpose, conjugate transpose, inverse of a matrix; diagonal, scalar, triangular matrices; similar matrices; nilpotent, idempotent, symmetric, skew-symmetric, hermitian, skew-hermitian matrices; general partitioned matrices, trace of a square matrix; row rank/column rank of a matrix (in terms of linear independence of row/column vectors of a matrix); theorem on equality of row rank and column rank of a matrix; elementary operations, row/column reduced echelon form of a matrix, rank of a matrix, elementary matrices, determination of rank by elementary operations, determination of inverse of a matrix by elementary operations.

(15 hours)

**Unit-II:**

Adjoint of a matrix, inverse in terms of adjoints; determinantal rank of a matrix; equality of rank and determinantal rank; systems of linear equations, homogeneous and non-homogeneous equations, consistency and non-consistent system of equations, solving systems of equations by determining rank of augmented matrix and rank of coefficient matrix, Gaussian elimination and Gauss Jordan Reduction Method. The inverse of a matrix (including the concept of G-inverse).

(15 hours)

**Unit-III:**

Vector spaces, subspaces, and algebra of subspaces; linear combination of vectors, linear span; linear independence, basis, and dimension. Linear transformations, range space, null space, rank, nullity, matrix representation of linear transformations; algebra of linear transformations, eigenvalues and eigenvectors, characteristic polynomial; determinant, Cayley-Hamilton Theorem, Quadratic forms and their different types.

(15 hours)

## Part – B (Practical)

### UNIT-IV: Practical

(30 hours)

Elementary operations of matrices. Determinant of a matrix. Finding the rank of a matrix (including REF). Problems based on partitioned matrices**.** Solution of equations by Gaussian elimination and Gauss Jordan Reduction method. Inverse of a matrix by adjoint and Gauss Jordan Reduction Method. Characteristic roots and characteristic vectors. Finding power of a matrix using Caley Hamilton Theorem.

### Suggested readings:


1. Banerjee, S. and Roy, A. (2014). Linear Algebra and Matrix Analysis, CRC
2. Biswas, S. (1997). A Textbook of Matrix Algebra, New Age International.
3. Gentle, James E. (2005). Matrix Algebra: Theory, Computations and Applications in Statistics, Springer Text in Statistics, Springer-Verlag, New York.
4. Gupta, S.C. (2008). An Introduction to Matrices (Reprint). Sultan Chand & Sons.
5. Hadley, G. (2002). Linear Algrbra. Narosa Publishing House (Reprint).
6. Kolman, B. and Hill, D. R. (2010). Elementary Linear Algebra with Applications, $10^{TH}$ Ed., Pearson.
7. Krishnamurthy, V., Mainra, V.P. and Arora, J.L. (2015). An Introduction to Linear Algebra, East West Press Pvt. Ltd., New Delhi.
8. Lay, D. C. (2000). Linear Algebra and its Applications, Addison Wesley.
9. Rao, A.R. and Bhimasankaram, P. (1992). Linear Algebra, Tata McGraw-Hill, New Delhi
10. S.K. Jain, S.R. Nagpaul (2015), First Course in Linear Algebra, P.B. Bhattacharya, New Age International.
11. Searle, S.R. (1982). Matrix Algebra useful for Statistics, John Wiley & Sons, New York.
12. Singh, B.M. (2008). Introductory Linear Algebra, South Asian Publishers Pvt. Ltd., New Delhi

## STA-252: Introduction to Statistical Inference

**75 Lecture Hours** **4 Credits**

**Course objectives:** To enable the students to gain knowledge and understanding of point and interval estimation and hypothesis testing fundamentals.

**Learning outcomes:** By the end of the course, students should have a solid theoretical foundation in statistical inference. The students should be able to effectively estimate population parameters and how to draw meaningful conclusions from statistical analyses through hypothesis testing

### Part – A (Theory)

**UNIT-I:**

Estimation-Point Estimation-Concepts of point estimation, Criterion of a good estimator, unbiasedness, sufficiency, consistency and efficiency. Cramer-Rao inequality and its uses, Cramer-Rao lower bound, Rao-Blackwell Theorem.

(15 hours)

**UNIT-II:**

Method of estimation: Likelihood function, method of maximum likelihood and method of moments. Their applications for estimate of parameters in Binomial, Poisson and Normal distribution. Mean square error (MSE). Minimum variance unbiased Estimation (MVUE). (15 hours)

**UNIT-III:**

Interval Estimation- Concept of Confidence intervals for means and differences of means and proportions and difference of proportions from sampling from Normal populations. Construction of confidence interval for the parameter of Binomial, Poisson and Normal distributions. Hypothesis testing for small samples: null and alternative hypothesis, types of error, p-values. (15 hours)

### Part – B (Practical)

**UNIT-IV: Practical**

(30 hours)

1. Estimation of parameters for Binomial, Poisson, and Normal distribution using method of moments.
2. Estimation of parameters for Binomial, Poisson, and Normal distribution using method of maximum likelihood.
3. Construction of confidence interval for the parameter Binomial, Poisson and Normal distributions.

**Suggested Readings :**


1. A M Goon, M K Gupta, B Dasgupta. Fundamental of Statistics, Vol & 2, World Press
2. E J Dudewicz, S N Mishra. Modern Mathematical Statistics,
3. S.C. Gupta, V.K. Kapoor, Fundamental of mathematical Statistics, Sultan Chand & Co.
4. P Mukhopadhyay. Applied Statistics, New Central Book Agency
5. A M Mood, F A Graybill, D C Boes. Introduction to the Theory of Statistics,
6. R V Hogg, A T Craig. Introduction to Mathematical Statistics, Collier Macmillan
7. F S Hiller, G J Libermann. Introduction to Operations Research, Mc Graw Hill

## STA – 253: Introduction to Sample Survey

**75 Lecture Hours** **4 Credits**

**Course Objective:** To introduce students to the fundamental concepts and principles of sampling theory. To provide students with the knowledge and skills to design sample surveys effectively, including determining the sample sizes and selecting appropriate sampling techniques.

**Learning Outcomes:** Students can understand the tools and techniques of sample survey, including population, sample, sampling frame, sampling methods, and sampling distributions.

### Part – A (Theory)

**Unit-I:**

Sample Survey: Concept of population and sample, Comparison of census and sample, Principles of sample survey. Limitations of sample survey. Sampling and Non-sampling errors. Types of Sampling: Non-probability and Probability sampling. Simple Random Sampling (SRS): Simple random sampling with and without replacement (SRSWR and SRSWOR), unbiased estimators of population total, mean, and their variance and its confidence interval. Estimation of proportion, Determination of sample size. Merits and drawbacks of Simple random sampling.

(15 hours)

**Unit-II:**

Stratified Random Sampling: Stratified sampling with SRSWR and SRSWOR within each stratum: estimation of population mean, population total and their variances and its confidence interval, proportional allocation, optimum allocation, comparison of stratified sampling with SRS.

(15 hours)

**Unit-III:**

Estimation of proportion in stratified sampling. Systematic sampling: estimation of population mean, total and variance and its confidence interval. Systematic sampling vs simple random sampling. Systematic sampling vs stratified random sampling. Advantages and disadvantages of Systematic sampling.

(15 hours)

## Part – B (Practical)

### Unit-IV: Practical

(30 Hours)

Problems based on estimation of population parameters by SRSWR, SRSWOR sampling and construction of confidence interval.

Problems based on estimation of population parameters by Stratified sampling and construction of confidence interval.

Problems based on estimation of population parameters by Systematic sampling and construction of confidence interval.
Comparison of SRS, Stratified and Systematic sampling, and Relative efficiency.

### Suggested Readings:


1. Singh, D. (2018), 'Theory and Analysis of Sample Survey Design', New age International Publishers, ND.
2. Sampath, S. (2005), 'Sampling Theory and Methods', Alpha science International.
3. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S. and Asok, C. (1984), 'Sampling Theory of Surveys with Applications', Asia Publishing House.
4. Chaudhuri, A. (2010), 'Essentials of Survey Sampling', Prentice Hall of India.
5. Gupta, S.C.&Kapoor, V. K. (2014), 'Fundamentals of Applied Statistics', Sultan Chand and Sons,.
6. Goon, A. M., Gupta, M. K. and Dasgupta, B. (1999), 'Fundamental of Statistics', Vol. II, World Press, Kolkata.
7. Bansal, Archana. (2017). Survey Sampling. Narosa Publishing House Pvt Ltd. New Delhi.
8. Ladusingh, Laishram (2018). Survey Sampling Methods, PHI learning Private Limited.
9. Cochran W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.

## STA – 300: Introduction to Design of Experiments

**75 Lecture Hours** **4 Credits**

**Course Objectives:** To develop a systematic method to determine the relationship between factors affecting a process and the output of that process. To make the student understand how to design experiments to optimize processes, products, or systems by identifying significant factors and their interactions.

**Learning Outcomes:** By the end of the course, students should be able to familiarize themselves with the basic designs and their applications and also with factorial experiments for industrial and other uses.

### Part – A (Theory)

**UNIT-I:**

Definition of ANOVA, Analysis of Variance for one-way and two-way classification with one observation per cell under Fixed Effect Model. Fundamental Principles of Design.

(15 hours)

**UNIT-II:**

Basic Designs: Complete Randomised Design (CRD), Randomised Block Design (RBD), Latin Square Design (LSD) with their analyses. Estimation of one missing observation for RBD and LSD.

(15 hours)

**UNIT-III:**

Factorial experiments: Definitions, advantages and limitations, notations and concepts, Analysis of Factorial Experiments: $2^2$ and $2^3$, main effects and interactions.

(15 hours)

### Part – B (Practical)

**UNIT-IV: Practical**

(30 hours)

1. Problems based on Analysis of Variance for one-way classification.
2. Problems based on Analysis of Variance for two-way classification (with one observation per cell).
3. Problems based on analysis of CRD, RBD and LSD.
4. Problems based on Estimation of one missing value in CRD, RBD and LSD.
5. Problems based on Analysis of $2^2$ designs and $2^3$ designs

**Suggested readings:**


1. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
2. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
3. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8th Edn. World Press, Kolkata.
4. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
5. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
6. Joshi, D.D. (2003), Linear Estimation and Design of Experiments, New Age International Publishers, New Delhi.

## STA – 301: Testing of Hypothesis

**75 Lecture Hours** **4 Credits**

**Course objectives:** This course covers hypothesis testing for various scenarios, emphasizing tests of significance for small and large samples. Students will learn to formulate hypotheses and to apply optimal tests. Students will be able to evaluate tests and interpret results accurately. Additionally, students will be able to explore the application of likelihood ratio tests.

**Learning outcomes:** Upon completing this course, students will understand the basic principles and methods of hypothesis testing.

### Part – A (Theory)

**UNIT-I:**

Statistical hypotheses - Simple and composite, statistical tests, critical region, Type-I and Type-II errors, size and power of a test, Definition of: Most Powerful (MP), Uniformly Most Powerful (UMP), and unbiased test.

(15 hours)

**UNIT-II:**

Testing for mean and variance of univariate normal distribution. Testing for the significance of correlation and regression coefficients. Paired t-test. Hypothesis testing for large samples: Tests for single mean, single proportion, difference of two means, and two proportions. Chi-Square Test for goodness of fit.

(15 hours)

**UNIT-III:**

Neyman-Pearson Lemma and its application in testing of hypothesis related to Binomial, Poisson, Normal, and Exponential distributions. Power functions of UMP test with simple illustrations. Likelihood Ratio tests for parameters of Binomial and Poisson.

(15 hours)

### Part – B (Practical)

**UNIT-IV: Practical**

(30 Hours)

1. Problems on test of significance for a single mean and single proportion.
2. Problems on test of significance for difference of means and two proportions.
3. Problems on test for significance of correlation and regression coefficients
4. Problems on Paired t-test.
5. Problems on Chi-Square test for goodness of fit.

**Suggested readings:**


1. Casella, G. & Berger, R. L. (2007), 'Statistical Inference', Cengage Learning India Pvt. Ltd., ND.
2. Bhuyan, K. C. (2010), 'Probability Distribution Theory & Statistical Inference', New Central Book Agency.
3. Rao, C. R. (2008), 'Linear Statistical Inference & Its Applications', John Wiley & Sons.
4. Rao, Tanis and Hogg (2011), 'Probability & Statistical Inference', Pearson.
5. Hogg, R. V., Tanis, E. and Zimmerman, D. (2013), 'Probability & Statistical Inference', 9th Ed., Pearson.
6. Goon, A. M., Gupta, M. K. and Dasgupta, B. (1999), 'Fundamental of Statistics, Vol. I', World Press, Kolkata.
7. Das, Kishore K. and Bhattacharjee, D. (2008), 'A Treatise on Statistical Inference and Distribution', Asian Book House, ND.
8. Hogg, R. V. and Craig, A. T. (2002), 'Introduction to Mathematical Statistics', 5TH Ed., Person Education, ND.
9. Gupta, S. C. & Kapoor, V. K. (2000), 'Fundamentals of Mathematical Statistics', Sultan Chand and Sons, ND.
10. Mood, A.M. and Graybill, F.A. (1963), "Introduction to the theory of Statistics", McGraw Hill Book Co., NY.
11. Goon, A.M., Gupta, M.K. and Das Gupta, B. (2003), "An outline of Statistical Theory", Vol. II, World Press Pvt. Ltd.
12. Kendall, M.G. and Stuart, A. (), "The advanced Theory of Statistics", Vol. II Charles Griffin.
13. Rohatgi, V.K. and Saleh, A.K.M. (2001), "An Introduction to Probability and Statistics", 2nd Ed., John Wiley.
14. Chaudhuri, Salil Kumar and Chakrabarty, A. (2010), "Statistical Methods", Asian Book House, ND.

## STA – 302: APPLIED STATISTICS

**75 Lecture Hours** **4 Credits**

**Course Objectives**: The broad objective of this paper is to equip the students with the knowledge and skills necessary to apply statistical concepts and methods in the fields of demography, economics and industries.

**Learning Outcomes:** By the end of the course, students should be equipped with the knowledge and skills necessary to effectively used the statistical concepts and methods to analyze data relating to population, economics, and industries.

### Part – A (Theory)

**UNIT-I:**

Demographic methods: sources of Demographic data (Registration, Census and SRS), Natural increase in population, measurements of mortality: Crude Death Rate, Age-Specific Death Rate, IMR, MMR, Standardized death rates. Complete Life Table, Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR. Basic idea of migration, nuptiality and Population Projection (using Logistic and exponential curve).

(15 hours)

**UNIT-II:**

Concept of Index Numbers, Problems on Construction of Index numbers, Weighted means, price, quantity and value index numbers, choice of weights, Laspeyres', Paasche's, Dorbhish Bowley, Marshal-Edgeworth, Fisher's index numbers. Characteristics of an ideal Index numbers, tests of index numbers (Time and factor Reversal tests). Consumer price Index, Wholesale price index number and index of industrial production.

(15 hours)

**UNIT-III:**

Statistical Process and Product Control, Theory of Control Charts, Control Limits, tools for Statistical Quality Control. Control charts for Mean, $\boldsymbol{\sigma}$, R, p and c. Advantages and limitations of AQC, Acceptance Sampling Plan, Producer's and Consumer's Risk, ASN Curve, OC curves, Single and Double Sampling Plan, CUSUM chart.

(15 hours)

## Part – B (Practical)

### UNIT-IV: Practical

(30 hours)

1. To calculate CDR and Age Specific death rate for a given set of data
2. To find Standardized death rate by both Direct and Indirect Methods
3. To construct a complete life table and finding the missing entries of a life table.
4. To calculate CBR, GFR, SFR, TFR for a given set of data.
5. To calculate Crude rate of Natural Increase, GRR, NRR
6. Population Projection using Logistic and exponential curves
7. Calculation of price, quantity, and value index numbers.
8. Construction of Consumer and Wholesale Price Index numbers
9. Related problems based on Index numbers
10. Construction of X-bar, R-chart, p-chart and c-chart.
11. Single and Double sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves

### Suggested readings:


1. Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition World Press, Kolkata.
3. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals Of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons.
4. Montogomery, D. C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, rd Edition reprint, Wiley India Pvt. Ltd.
5. Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
5. Ehrlich,B.Harris(2002):Transactional Six Sigma and Lean Servicing, 2nd Edition St. Lucie Press
6. Hoyle, David (1995): ISO Quality Systems Handbook, Heinemann Publication. 2nd Edition, Butterworth
7. Keyfitz, N and Caswell. H (2005): Applied Mathematical Demography (3rd edition), Springer.
8. Ramakuar, R. and Gopal, Y.S. (1986): Technical Demography. Wiley Eastern Ltd
9. Mishra B.D. (1980): An Introduction to the Study of Population, South Asian Publication.

## STA - 303: THEORY OF ATTRIBUTES, CATEGORICAL DATA AND DEMAND ANALYSIS

**75 Lecture Hours** **4 Credits**

**Course objective**: The objective of this course is to help students analyze the qualitative types of characteristics using quantitative measurements and to interpret the results. Students will be introduced to concepts of demand and supply, elasticity of demand

**Course Outcome:** With the completion of the course a student will be able to define attributes, order of class and class frequency, explain independence and association of attributes. Understand the concepts of demand and supply, and fitting of Pareto's curve

### Part – A (Theory)

**UNIT-I**:

Analysis of Categorical data, consistency of categorical data; Independence of Attributes: Concept and Criterion of Independence. Association of Attributes: Concept and Various measures (Yule's Coefficient of Association, Coefficient of Colligation).

(15 hours)

**UNIT-II:**

Demand analysis: Static Law of Demand and Supply, Price and Income Elasticity of Demand. Income Distribution, Pareto distribution. Fitting of Pareto's Law, Lorenz Curve and Estimation of elasticity. Gini's Coefficient.

(15 hours)

**UNIT-III**:

Indian Official Statistics: Present Official Statistical System in India. Methods of collection of Official Statistics, Their Reliability and Limitations. Principal Publications containing Data on topics such as Population, agriculture, Industry, Trade, Prices, Labour and Employment, Transport and Communications, Banking and Finance. Various Official Agencies responsible for Data Collection and Their Main Functions.

(15 hours)

## Part – B (Practical)

**UNIT-IV**: **Practical**

Problem on consistency independence and association of attributes

Problems on laws of demand and supply, elasticity of demand

Fitting of pareto's Law, Lorenz Curve, Gini coefficient

**Suggested Readings:**


1. Fundamental of Statistics, Himalaya Publishing House, 7thEdition.
2. Gupta S.C. and V.K. Kapoor (2020), Fundamental of Mathematical Statistics, Sultan Chand and Co. 12th Edition.
3. Hogg, R. V. McKean J. W. and Craig, A. T. (2012), Introduction to Mathematical Statistics, Pearson 7th Edition.
4. Johnson, R.A. and Bhattacharyya, G.K. (2006), Statistics: Principles and methods. 5th Edition, John Wiley & Sons, New York.
5. Medhi, J. (2005), Statistical Methods, New Age International.
6. Ross, S.M. (2014), Introduction to Probability and Statistics for Engineers and Scientists, 5th Edition, Academic Press.
7. Tukey, J.W. (1977), Exploratory Data Analysis, Addison-Wesley Publishing Co. References

# STA - 304:  Internship

## STA – 350: Non – Parametric & Sequential Procedures

**75 Lecture Hours** **4 Credits**

**Course Outcome**: The objective of this course is to provide students with a solid understanding of non-parametric and sequential procedures in statistics. By the end of the course, students should be able to apply non-parametric tests effectively, understand the principles of sequential testing, and interpret the results in practical scenarios.

**Learning Outcome**: Students will understand the concept of non-parametric tests and their advantages and drawbacks compared to parametric methods. They can apply various non-parametric tests for single-sample and two-sample problems of location and scale. Analyze data using sequential testing methods such as the Sequential Probability Ratio Test (SPRT) and Wald's SPRT. Interpret the results of non-parametric tests and sequential tests in real-world applications

### Part – A (Theory)

**UNIT-I:**

Introduction to Non Parametric Test: Definition of Non – Parametric test, advantages and drawbacks of Non- parametric Methods, Performance of NP test, Parametric versus Non – parametric, distribution free methods, areas of applications, non - parametric tests – Run test, sign test. Asymptotic Relative Efficiency.

(15 hours)

**Unit-II:**

Univariate Single – Sample Problem of Location: Kolmogorov – Smirnov One sample Test, Sign Test, the two – sided Sign Test, Wilcoxon Signed – Ranks Test: One – Sample Location Test.

Univariate Two – Sample problem of Location and scale: The Wilcoxon – Mann – Whitney Test, The Normal Score Test, Median Test, Kolmogorov – Smirnov Test (Two Sample Problem).

Kruskal – Wallis Test: A Test for equality of locations of k (> 2) Independent Populations (Non Parametric One Way ANOVA)

(15 hours)

**Unit-III:**

Sequential Test – Introduction to SPRT, Wald’s SPRT with illustrations. Approximate OC and ASN Functions for test regarding parameters of binomial and normal distributions.

(15 hours)

## Part – B (Practical)

**Unit-IV: (**Practical)

(30 hours)

Run Test for small sample test and large sample test, sign test – for univariate and bivariate population (one Sample and two sample), Kolmogorov – Smirnov test (One sample and two sample), Wilcoxon rank test ( one Sample and two Sample), Mann-Whitney Test ( two sample), Median Test (two sample),SPRT for binomial distribution, normal distribution for finding OC and ASN function.

**Suggested Readings**:


1. Bhattacharya, D. & Chowdhury, S. R. (2019). Probability and Statistical Inference: Theory and Practice (3rd Edition), UN Dhur and Sons.
2. Casella, G. & Berger, R. L. (2024). Statistical Inference, 2nd Edition, Chapman and Hall.
3. Conover, W. J. (1999). Practical Nonparametric Statistics, 3rd Edition, Wiley Series.
4. Gibbons J. D. (1996) Non – Parametric Methods for Quantitative Analysis, 3rd Edition, American Science Press.
5. Hogg, R. V., Tanis, E. A., & Zimmerman, D. (2019). Probability and Statistical Inference, 9th Edition, Pearson.
6. Hollander, M., Wolfe, D. A., & Chicken E. (2014). Nonparametric Statistical Methods (2nd Edition), Wiley.
7. Lehmann, E. L. (1998). Nonparametrics: Statistical Methods Based on Ranks, 1st Edition, Prentice Hall.
8. Rajagopalan, M. & Dhanavanthan, P. (2012). Statistical Inference, PHI learning.
9. Siegel, S., & Castellan, N. J. (1988). Nonparametric Statistics for the Behavioral Sciences, 2nd Edition, McGraw-Hill, New York.
10. Srivastava, M. K. & Srivastava, N. (2012). Statistical Inference: Testing of Hypothesis, PHI Learning.

## STA – 351: Linear Estimation and Linear Models

**75 Lecture Hours** **4 Credits**

**Course Objectives**: The objective of this course is to equip students with a comprehensive understanding of the fundamental concepts of linear models including parameter estimation and inference for such models. It also aims to equip students in understanding the theoretical concept of linear estimation and linear models, and effectively apply them in real data set.

**Learning Outcomes:** After completing this course, students should be equipped with the knowledge of linear estimation and linear models, critically evaluate them and effectively apply to solve practical problems in various fields.

### Part – A (Theory)

**UNIT-I:**

Theory of linear estimation. estimability of linear parametric functions, Best Linear Unbiased estimator (BLUE), method of least squares, Gauss-Markov theorem, Gauss-Markov linear model.

(15 hours)

**UNIT-II:**

Variance and covariance of Least Square estimators, estimation of error variance. Tests of hypotheses, linear models with restricted hypothesis, confidence intervals.

(15 hours)

**UNIT-III**

Concept of model matrix and its use in estimation, fitting linear models in matrix form. Generalized linear model – introduction and definition, Generalized least squares, application of generalized linear model.

(15 hours)

### Part – B (Practical)

**UNIT-IV: Practical** (30 hours)

Estimability when X is a full rank matrix, Estimability when X is not a full rank matrix, Least square estimation of model parameters, Fitting of the linear model, Tests for Linear Hypothesis, Construction of Confidence interval

**Suggested readings:**


1. Bapat, R. B. (2012). Linear Algebra and Linear Models, Springer.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016): Fundamentals of Statistics. Vol. II, World Press, Kolkata.
3. Joshi, D.D. (1987). Linear Estimation and Design of Experiments, Wiley Eastern, New Delhi
4. Kshirsagar, A. M. (1983) A Course in Linear Models, Taylor and Francis.
5. Montgomery, D.C., Peck, E.A. and Vining, G.G. (2006) Introduction to Linear Regression Analysis, Wiley.
6. Rencher, A.C., Schaalje, B. G. (2007). Linear Models in Statistics, 2nd Edition, Wiley.
7. Searle, S. R. (1971). Linear Models. Wiley, New York.
8. Sengupta, D. and Jammalamadaka, S.R. (2003). Linear Models: An Integrated Approach, World Scientific.
9. Zimmerman, D. L. (2020). Linear model theory: with examples and exercises, Springer.

## STA – 352: Regression Analysis

**75 Lecture Hours** **4 Credits**

**Course Objectives**: The objective of this course is to equip students with a comprehensive understanding on the fundamental concepts of regression analysis. Students will learn regression models and their applications in analysing relationships between variables, the assumptions underlying regression analysis and checks the validity of regression assumptions, detect influential observations, and identify potential problems such as multicollinearity.

**Learning Outcomes:** After completing this course, students should be equipped with the knowledge and skills necessary to conduct regression analysis effectively, critically evaluate regression models and apply them to solve practical problems in various fields.

### Part – A (Theory)

**UNIT-I:**

Bivariate and Trivariate data: Scatter diagram, product moment correlation coefficient and its properties. Simple regression, principle of least squares, fitting of linear regression and related results. Multiple regression involving two independent variables- multiple and partial correlation coefficients (fitting of second degree polynomial). Concept of intraclass correlation coefficient.

(15 hours)

**UNIT-II:**

Estimation and tests of regression parameters in simple and multiple linear regression under usual assumptions, related interval estimation. Violation of usual assumptions concerning normality, homoscedasticity and collinearity. Diagnostics using probability plots.

(15 hours)

**UNIT-III:**

Concept of non-linear regression, fitting of curvilinear regression. Concept of Logistic regression- model for dichotomous data with single and multiple (only two) explanatory variables, its assumptions and applications. Correlation ratio and correlation index.

(15 hours)

## Part – B (Practical)

### UNIT-IV: Practical

(30 hours)

1. Computation of correlation and regression coefficients (ungrouped and grouped data).
2. Fitting a straight line, parabola by least squares method.
3. Computation of multiple and partial correlation coefficients.
4. Computation of multiple regression.
5. Fitting of second degree polynomial.
6. Estimation of regression coefficients by least square method and construction of confidence intervals.
7. Testing of hypothesis concerning regression coefficients, correlation coefficients for simple and multiple regression.
8. Problem based on Residual plot.

### Suggested readings:


1. Montgomery, D.C., Paek, E. A. and Vining G.G. (2010), Introduction to Linear Regression Analysis, 3rd Ed., Wiley.
2. Chatterjee, S. and Price, P. (1991), Regression Analysis by Example, 2nd Ed., John Wiley.
3. Draper, N. R. and Smith, H. (2011). Applied Regression Analysis, John Wiley, New York.
4. Seber, G. A. F and Lee Alan J. (2014). Linear Regression Analysis, John Wiley, New York.
5. Searle, S. R. (1971). Linear Models. Wiley, New York.
6. Rencher, Alvin.C. and Schaalje, G.Bruce. (2007) Linear Models in Statistics, 2nd Ed., Wiley.
7. Biswas, S (2014) A Linear Models Approach to Regression Analysis and its Applications, 2nd Ed., New Central Book Agency.
8. Seber, G. A. F. and Wild, C. J. (2003). Non-linear Regression, Wiley.
9. Gupta, S. C. & Kapoor, V. K. (2000), 'Fundamentals of Mathematical Statistics', Sultan Chand and Sons, ND.

**STA – 353: Advanced Survey Sampling**
**(Contact Hours: 75, Credits: 4)**

**75 Lecture Hours** **4 Credits**

**Course Objectives**: To equip the students with the knowledge and skills necessary to conduct and analyze data from sample surveys. The students will be introduced to the various sampling techniques such as LSS, CSS, Cluster sampling and Two stage sampling. The students will understand the advantages, disadvantages, and appropriate applications of each technique.

**Learning Outcomes:** By the end of the course, students should be equipped with the knowledge and skills necessary to conduct, analyze, and report on sample surveys effectively.

**Part – A (Theory)**

**UNIT-I:**

Linear Systematic Sampling – concept and populations with linear trend. Basic idea of interpenetrating sub-samples (IPSS). Circular Systematic sampling (CSS) – concept and estimation of the population mean and population total and their variances, estimation of variance using IPSS. Ratio, difference and Regression methods of estimation under SRSWR and SRSWOR - Bias and MSE and their large sample estimation.

(15 hours)

**UNIT-II:**

Cluster sampling: concept and single stage cluster sampling with equal size cluster using SRSWR and SRSWOR. Estimation of population mean and total, variance in terms of intraclass correlation. Estimation of variance. Basic idea of two stage sampling and sub sampling.

(15 hours)

**UNIT-III:**

Two Stage Sampling: with equal size first stage units (FSUs) SRSWR at both stages, SRSWOR at both stages, SRSWR at first stage and SRSWOR at second stage, SRSWOR at first stage and SRSWR at second Stage- Estimation of population mean per second stage unit (SSUs) and its sampling variance. Estimation of population total

(15 hours)

## Part – B (Practical)

**Practical**

(30 hours)

**UNIT – IV:**

Problem based on estimation of population mean and totals and standard errors for LSS and its comparison with stratified random sampling and SRSWOR. Problem based on sampling variance in case CSS in terms of intraclass correlation coefficient and its efficiency with respect to SRSWR and SRSWOR. Problem based on ratio and regression methods of estimation using SRSWR and SRSWOR. Problem based on estimation of mean, variance and their standard errors of the estimate in cluster sampling with equal size cluster. Problem based on estimation of mean, total and their standard errors with SRSWR and SRSWOR in two stage sampling.

**Suggested readings:**


1. Bansal, Archana. (2017). Survey Sampling. Narosa Publishing House Pvt Ltd. New Delhi.
2. Chaudhuri, A. (2010). Essentials of Survey Sampling, Prentice Hall of India.
3. Cochran W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.
4. Goon, A. M., Gupta, M. K. and Dasgupta, B. (1999). Fundamental of Statistics, Vol. II, World Press, Kolkata.
5. Gupta, S.C.&Kapoor, V. K. (2014), Fundamentals of Applied Statistics, Sultan Chand and Sons,.
6. Ladusingh, Laishram (2018). Survey Sampling Methods, PHI learning Private Limited.
7. Mukhopadhyay, P. (2008). Theory and Methods of Survey sampling. 2nd Edition, PHI Learning.
8. Sampath, S. (2005). Sampling Theory and Methods, Alpha science International.
9. Singh, D. (2018). Theory and Analysis of Sample Survey Design, New age International Publishers, New Delhi.
10. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S. and Asok, C. (1984), Sampling Theory of Surveys with Applications, Asia Publishing House.