

**LOCF for UG-Statistics, Department of Statistics, Manipur University**

**Learning Outcomes based Curriculum Framework  
(LOCF)  
for Statistics  
Undergraduate Programme B.A./B.Sc. (Honors) 2022**

## PREAMBLE

Statistics is a science which deals with numerical data in which raw data is converted into useful information. Statistics as a subject is an important branch of knowledge and is devoted to various techniques of collection, presentation, analysis and interpretation of data. It is a science of learning from data. The subject provides tools for making decisions when conditions of uncertainty prevail. In the modern times where large amount of data can be collected through the use of information technology, Statistics has become a very useful tool to analyse these data and extract useful information which primarily helps people in making decision in the most beneficial way. Hence Statistical tools and techniques are used in almost all fields which are indispensable for people working in fields like agriculture, business, management, economics, finance, insurance, education, biotechnology and medical science, etc. For the last two decades, huge amount of data has been handled with the help of Computers and more sophisticated statistical techniques are employed in an effective manner to draw valid conclusions. Thus, the knowledge of different aspects of Statistics has become beneficial in the present times. Consequently, the demands for employable statisticians are on the increase day by day in various fields of research, business, management, information technology, etc. The syllabi of the Bachelor's Certificate, Bachelor's Diploma, Bachelor's Degree and Bachelor's Degree with Honours degree course in Statistics are framed in such a way that the students at the end of the course, can acquire adequate knowledge of Statistical techniques in both theory and practice. This will help the students for pursuing higher studies and simultaneously can apply statistical tools judiciously to a variety of data sets related to different fields.

### 1. Introduction

B.A/ B.Sc. (Honours.) Statistics programme consists of 182 credits spread over eight semesters. Each credit has one hour of class room teaching per week. This programme emphasizes both theory and applications of statistics and is structured to provide knowledge and skills in depth necessary for the employability of students in industry, other organizations, as well as in academics.

### 2. Learning Outcomes Based Approach to Curriculum Planning

#### 2.1 Nature and Extent of the B.A./B.Sc. (Honours) Programme

The B.A./B.Sc. (Honours.) Statistics Programme has some unique features such as independent projects, a number of elective courses including practical training on realistic problems, and extensive insight into statistical computations using standard statistical packages. Standard statistical packages, namely, MINITAB, MATLAB, R, MATHEMATICA, SAS, S-PLUS, STATISTIKA, etc. are used in all practical courses and project work. The course has been designed in such a way that besides the core courses, a student can opt for outcome based elective courses from the streams such as *Financial Statistics*, *Bio- Statistics*, *Geo-Statistics*, *Actuarial Statistics*, *Computational Statistics*, *Time Series*, *Clinical Trials*, *Epidemiology*, etc.

The independent project work is one of the important components of this programme which will focus on one of the streams opted by the candidate.

B.A./B.Sc. (Honours) Statistics programme is of four years duration, with eight semesters pattern.

- During first two semesters, students will be given the basic information that includes methods of data representation and summarization. Further, they will be introduced to probability and distributions along with applications.
- During third and fourth semesters, students are expected to study statistical inference, regression analysis, numerical analysis and sampling techniques.
- During fifth and sixth semesters, some theory papers and practicals deal with theoretical as well as applications of statistics.
- During seventh and eighth semesters, some theory papers and practicals deal with theoretical as well as applications of Statistics. Besides, in eighth semester, they are supposed to take up a Project Work preferably on a problem related to social data, agricultural data, health data, etc.

## 2.2 Aims of Bachelor's degree Programme in Statistics

- To prepare graduates who are not only statistically sound but also capable of using their appropriate statistical skills in interdisciplinary areas such as finance, health, agriculture, business, industry, telecommunication, bio-statistics etc. As a result, they can pursue their future career either in the core field or in the applied field of Statistics.
- To familiarize students with computational techniques and software used in the statistical arena.
- To provide a solid ground in the best practices of collating and disseminating information.
- To prepare students for undertaking further study.
- To enable students to construct practicable statistical situations in the real-world.

## 3. Graduate Attributes in Statistics

- **Disciplinary Knowledge:** The proposed curriculum is expected to provide the students a sound knowledge of Statistics covering various aspects. As a result, they will not only appear appropriate for pursuing higher studies in the subject but also develop skill to apply the statistical tools in the real life problems.
- **Critical Thinking:** The proposed course is designed to enrich the students with ability to examine the various statistical issues in a more logical and methodical manner. It is expected that the students will strengthen themselves logically, computationally and analytically.
- **Problem Solving:** The students will be able to critically examine various hypotheses and research queries, and will be able to identify and consult relevant resources to find their rational answers.
- **Analytical Reasoning:** The students are expected to develop a capability to identify logical flaws and loopholes in analyzing and synthesizing data for drawing conclusions.
- **Research Related Skills:** The students should be able to develop original thinking for formulating new problems and providing their solutions. As a result, they will be able to develop research related skills for their own subject as well as for those who are practicing Statistics.
- **Communication Skills and Team Work:** The students are expected to develop effective and confident Communication skill after completion of the course. They will have an ability to work in a team as well as in isolation.
- **Moral and Ethical Awareness:** After completion of the course, the students are expected to develop ethical and social responsibility as well. As a result, the students will be able to identify ethical issues, avoid unethical behaviour such as fabrication, falsification or misrepresentation and misinterpretation of data.
- **Scientific Reasoning:** The students will be able to analyse, interpret and draw appropriate conclusions from both quantitative and qualitative data and critically evaluate ideas, evidence and experiences with an unbiased and consistent approach.
- **Reflective thinking:** The students should be sensitive to real experiences with respect to self, society and nation.
- **Information/Digital literacy:** The proposed course is expected to develop digital literacy among the students for using ICT in different learning situations. The students should be able to equip themselves with in depth programming and simultaneously use appropriate Statistical software for advanced Statistical computing with high level graphical interface.
- **Self-directed Learning:** The students are expected to be familiar with data collection, compilation, analysis and interpretation and writing of project reports independently.
- **Multicultural Competence:** The students are expected to be aware of values and beliefs of different cultures and have a global perspective by examining various forms of primary and secondary data resources.

- **Leadership Readiness/Qualities:** The students will be capable of mapping out the tasks of a team or an organization, formulating an inspiring vision, building a team for achieving the desired objectives, motivating and inspiring team members accordingly, and using management skills to guide people in the right direction smoothly and efficiently.
- **Lifelong Learning:** The proposed course is designed to develop independent, coherent and decisive thoughts among the students that will ultimately develop competency in their lives. Simultaneously, they will develop entrepreneurship and intrapreneurship aptitude. This latter aspect will help them achieve risk-taking and innovative ability, an essential requirement of any large organization.

#### 4. Qualification Descriptors

***Qualification descriptors for a Bachelor's Degree with honours:*** The qualification descriptors for a Bachelor's degree with honours will demonstrate (i) a systematic, extensive, coherent knowledge of an academic field of study and its applications, links to interdisciplinary areas of study with a critical knowledge of the subject and a number of emerging issues, (ii) procedural knowledge that creates professionals in the field of, teaching, government and public services, (iii) skills in areas related to specialization and current developments in Statistics.

- Demonstrate skills in collection of relevant quantitative and/or qualitative data, analysis and interpretation of data using appropriate statistical methodologies.
- Use knowledge, understanding and skills for critical assessment of a wider range of ideas and complex problems and issues relating to the chosen field of study.
- Communicate the results of studies undertaken in statistics in arrange of different contexts using them in concepts, constructs and techniques of the subject.
- Address one's learning needs relating to current and emerging areas of study, making use of research, development and professional materials as appropriate, including those related to new frontiers of knowledge.
- Apply one's statistical knowledge and skills to new contexts and to identify and analyse problems and issues and seek solutions to real-life problems.
- Demonstrate subject-related skills that are relevant to some of the job trades and employment opportunities.

#### 5. Programme Learning Outcomes in B.A/B.Sc. (Hons.)Statistics

The student graduating with the Degree B.Sc. (Honors) Statistics should be able to

1. Demonstrate the ability to use skills in Statistics and its related areas of technology for formulating and tackling Statistical related problems and identifying and applying appropriate principles and methodologies to solve a wide range of problems associated with Statistics.
2. Acquire
  - (i) A fundamental/systematic or coherent understanding of the academic field of Statistics, its different learning areas and applications in Medical Statistics, Actuarial Statistics, Agricultural Statistics, Geo-Statistics, Financial Statistics, Population Statistics, Financial Econometrics, Clinical Trials and Epidemiology, Queuing Theory, Stochastic Processes, etc.,
  - (ii) Procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Statistics, including professionals engaged in research and development, teaching and government/public service;
  - (iii) Skills in areas related to one's specialization area within the disciplinary/subject area of Statistics and current and emerging developments in the field of Statistics.
3. Recognize the importance of statistical modeling simulation and computing, and the role of approximation and mathematical approaches to analyze the real world problems.
4. Plan and execute Statistical related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report -



accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Statistics.

5. Demonstrate relevant generic skills and global competencies such as

(i) Problem-solving skills that are required to solve different types of Statistics- related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary-area boundaries;

(ii) Investigative skills, including skills of independent investigation of Statistics- related issues and problems;

(iii) Communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature;

(iv) Analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Statistics and ability to translate them in simple language when needed;

(v) ICT skills;

(vi) Personal skills such as the ability to work both independently and in a group.

6. Demonstrate professional behavior such as

(i) Being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism;

(ii) The ability to identify the potential ethical issues in work-related situations;

(iii) Appreciation of intellectual property, environmental and sustainability issues; and

(iv) Promoting safe learning and working environment.

## 6. Credit structure and total:

Credit structure

| Semester | Core(Credit) | DSE(Credit) | GEC(Credit) | AECC(Credit)                    | SEC (Credit) | VAC (Credit) | Semester Credit |
|----------|--------------|-------------|-------------|---------------------------------|--------------|--------------|-----------------|
| I        | Core-1 (6)   |             |             | AECC-1 (4)<br>English/MIL       | SEC-1 (4)    | VAC-1 (2)    | 24              |
|          | Core-2 (6)   |             |             |                                 |              | VAC-2 (2)    |                 |
| II       | Core-3 (6)   |             |             | AECC-2 (4)<br>Environmental Sc. | SEC-2 (4)    | VAC-3 (2)    | 24              |
|          | Core-4 (6)   |             |             |                                 |              | VAC-4 (2)    |                 |

**Exit option with Bachelor's Certificate in a Discipline on completion of courses equal to a minimum of 46 Credits**

|     |             |  |           |  |  |           |    |
|-----|-------------|--|-----------|--|--|-----------|----|
| III | Core-5 (6)  |  | GEC-1 (6) |  |  | VAC-5 (2) | 26 |
|     | Core-6 (6)  |  |           |  |  |           |    |
|     | Core-7 (6)  |  |           |  |  |           |    |
| IV  | Core-8 (6)  |  | GEC-2 (6) |  |  | VAC-6 (2) | 26 |
|     | Core-9 (6)  |  |           |  |  |           |    |
|     | Core-10 (6) |  |           |  |  |           |    |

**Exit option with Bachelor's Diploma in a Discipline on completion of courses equal to a minimum of 96 Credits**

|    |             |           |           |  |  |           |    |
|----|-------------|-----------|-----------|--|--|-----------|----|
| V  | Core-11 (6) | DSE-1 (6) | GEC-3 (6) |  |  | VAC-7 (2) | 26 |
|    | Core-12 (6) |           |           |  |  |           |    |
| VI | Core-13 (6) | DSE-2 (6) | GEC-4 (6) |  |  | VAC-8 (2) | 26 |
|    | Core-14 (6) |           |           |  |  |           |    |

**Exit option with Bachelor's Degree in a Discipline on completion of courses equal to a minimum of 140 Credits**

|      |             |                      |           |  |  |  |    |
|------|-------------|----------------------|-----------|--|--|--|----|
| VII  | Core-15 (6) | DSE-3 (6)            | GEC-5 (6) |  |  |  | 24 |
|      | Core-16 (6) |                      |           |  |  |  |    |
| VIII | Core-17 (6) | DSE-4 (6)<br>Project | GEC-6 (6) |  |  |  | 24 |
|      | Core-18 (6) |                      |           |  |  |  |    |

**Award of Bachelor's Degree with Honours in a Discipline on completion of courses equal to a minimum of 182 Credits**

**Credit total**

| Course                                                                                                                                  | Credits            |
|-----------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| <b>I. <u>Core Course</u></b>                                                                                                            |                    |
| (18 Theory papers of 4 credits each)                                                                                                    | $18 \times 4 = 72$ |
| (6 Practicals of 4 credits each)                                                                                                        | $6 \times 4 = 24$  |
| (2 Practicals of 6 credits each)                                                                                                        | $2 \times 6 = 12$  |
|                                                                                                                                         | -----              |
|                                                                                                                                         | Total 108 credits  |
| <b>II. <u>Elective Course</u></b>                                                                                                       |                    |
| <b>A. Discipline Specific Elective (DSE)</b>                                                                                            |                    |
| (3 Theory papers of 4 credits each)                                                                                                     | $3 \times 4 = 12$  |
| (3 Practicals of 2 credits each)                                                                                                        | $3 \times 2 = 6$   |
| (1 project of 6 credits)                                                                                                                | $1 \times 6 = 6$   |
| <b>B. Generic Elective/Interdisciplinary (GE)</b>                                                                                       |                    |
| (6 Theory papers of 4 credits each)                                                                                                     | $6 \times 4 = 24$  |
| (6 Practicals of 2 credits each)                                                                                                        | $6 \times 2 = 12$  |
|                                                                                                                                         | -----              |
|                                                                                                                                         | Total 60 credits   |
| <b>Optional Dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 8<sup>th</sup> semester.</b> |                    |
| <b>III. Ability Enhancement Courses</b>                                                                                                 |                    |
| <b>1. Ability Enhancement Compulsory Courses (AECC)</b>                                                                                 |                    |
| (2 Theory papers of 4 credits each)                                                                                                     | $2 \times 4 = 8$   |
| <b>2. Skill Enhancement Courses (SEC)</b>                                                                                               |                    |
| (2 Theory papers of 3 credits each)                                                                                                     | $2 \times 3 = 6$   |
| (2 Practicals of 1 credit each)                                                                                                         | $2 \times 1 = 2$   |
|                                                                                                                                         | -----              |
|                                                                                                                                         | Total 16 credits   |
| <b>Grand total: 184 credits</b>                                                                                                         |                    |

## 7. Course Structure

### SEMESTER –I

|         |                                            |        |    |
|---------|--------------------------------------------|--------|----|
| STC101T | Descriptive Statistics                     | Core   | 04 |
| STC101P | Practical –based on STC101T                | Core   | 02 |
| STC102T | Probability Theory-I & Distributions-I     | Core   | 04 |
| STC102P | Practical –based on STC102T                | Core   | 02 |
|         | Any one from AECC (English/MIL)            | AECC-1 | 04 |
| STS101T | Computational Techniques and R Programming | SEC-1  | 04 |
|         | Any one from the list of VAC               | VAC-1  | 02 |
|         | Any one from the list of VAC               | VAC-2  | 02 |

### SEMESTER II

|         |                                                              |        |    |
|---------|--------------------------------------------------------------|--------|----|
| STC103T | Statistical Methods – I                                      | Core   | 04 |
| STC103P | Practical –based on STC103T                                  | Core   | 02 |
| STC104T | Distributions - II, Estimation – I and Probability Theory-II | Core   | 04 |
| STC104P | Practical –based on STC104T                                  | Core   | 02 |
|         | Any one from AECC(Environmental Science)                     | AECC-2 | 04 |
| STS102T | Statistical Techniques for Research Methodology              | SEC-2  | 04 |
|         | Any one from the list of VAC                                 | VAC-3  | 02 |
|         | Any one from the list of VAC                                 | VAC-4  | 02 |

### SEMESTER III

|         |                                                           |          |    |
|---------|-----------------------------------------------------------|----------|----|
| STC205T | Statistical Methods-II and Index Number                   | Core     | 04 |
| STC205P | Practical based on STC205T                                | Core     | 02 |
| STC206T | Statistical Inference-I, Basic Mathematics and Matrices-1 | Core     | 04 |
| STC206P | Practical based on STC206T                                | Core     | 02 |
| STC207T | Sampling Techniques& Official Statistics                  | Core     | 04 |
| STC207P | Practical based on STC207T                                | Core     | 02 |
| STG201T | Introduction to Statistics I                              | GEC-1    | 04 |
| STG201P | Practical based on STG201T                                | GEC-1(P) | 02 |
|         | Any one from the list of VAC                              | VAC-5    | 02 |

### SEMESTER IV

|         |                               |          |    |
|---------|-------------------------------|----------|----|
| STC208T | Regression Analysis           | Core     | 04 |
| STC208P | Practical –based on STC208T   | Core     | 02 |
| STC209T | Statistical Inference-II      | Core     | 04 |
| STC209P | Practical –based on STC209T   | Core     | 02 |
| STC210T | Numerical Analysis            | Core     | 04 |
| STC210P | Practical –based on STC210T   | Core     | 02 |
| STG202T | Introduction to Statistics II | GEC-2    | 04 |
| STG202P | Practical –based on STG202T   | GEC-2(P) | 02 |
|         | Any one from the list of VAC  | VAC-6    | 02 |

**SEMESTER V**

|         |                                             |          |    |
|---------|---------------------------------------------|----------|----|
| STC311T | Optimization Techniques                     | Core     | 04 |
| STC311P | Practical –based on STC311T                 | Core     | 02 |
| STC312T | Statistical Quality Control and Reliability | Core     | 04 |
| STC312P | Practical –based on STC312T                 | Core     | 02 |
| STD301T | Time Series Analysis                        | DSE-1    | 04 |
| STD301P | Practical based on STD301T                  | DSE-1(P) | 02 |
| STG303T | Introduction to Probability                 | GEC-3    | 04 |
| STG303P | Practical based on STG303T                  | GEC-3(P) | 02 |
|         | Any one from the list of VAC                | VAC-7    | 02 |

**SEMESTER VI**

|         |                                       |          |    |
|---------|---------------------------------------|----------|----|
| STC313T | Design of Experiments                 | Core     | 04 |
| STC313P | Practical based on STC313T            | Core     | 02 |
| STC314T | Non-Parametric Inference              | Core     | 04 |
| STC314P | Practical based on STC314T            | Core     | 02 |
| STD302T | Applied Statistics                    | DSE-2    | 04 |
| STD302P | Practical based on STD302T            | DSE-2(P) | 02 |
| STG304T | Introduction to Statistical Inference | GEC-4    | 04 |
| STG304P | Practical based on STG304T            | GEC-4(P) | 02 |
|         | Any one from the list of VAC          | VAC-8    | 02 |

**Semester – VII**

|         |                                                  |          |    |
|---------|--------------------------------------------------|----------|----|
| STC415T | Real Analysis & Statistical Inference-III        | Core     | 04 |
| STC415P | Practical based on STC415T                       | Core     | 02 |
| STC416T | Linear Algebra, Matrices–II and Measure Theory-I | Core     | 04 |
| STC416P | Practical based on STC416T                       | Core     | 02 |
| STD403T | Survival Analysis                                | DSE-3    | 04 |
| STD403P | Practical based on STD403T                       | DSE-3(P) | 02 |
| STG405T | Introduction to Applied Statistics               | GEC-5    | 04 |
| STG405P | Practical Based on STG405T                       | GEC-5(P) | 02 |

**Semester - VIII**

|         |                                                                                           |          |    |
|---------|-------------------------------------------------------------------------------------------|----------|----|
| STC417T | Measure Theory-II & Statistical Inference-IV                                              | Core     | 04 |
| STC417P | Practical based on STC417T                                                                | Core     | 02 |
| STC418T | Linear Model, Sum of Squares, Sample Survey-IV                                            | Core     | 04 |
| STC418P | Practical based on ST418T                                                                 | Core     | 02 |
| STD404P | Project (based on sample survey/Design of experiments/Demography/Survival analysis/ etc.) | DSE-4(P) | 06 |
| STG406T | Introduction to Operations Research                                                       | GEC-6    | 04 |
| STG406P | Practical based on STG406T                                                                | GEC-6(P) | 02 |

**Discipline Specific Elective Papers (6 credits each) (Any 3 papers to be selected and project in 6<sup>th</sup> semester is compulsory)**

STD301T: Time Series Analysis

STD302T: Applied Statistics

STD403T: Survival Analysis

STD404P: Project (based on Sample Survey/Design of Experiments/Demography/Survival Analysis/ etc.)) (Compulsory) Project may be in 8<sup>th</sup> semester

**Generic Electives/Interdisciplinary Papers (6 credits each) (Statistics students will opt 6 GE papers offered by other Departments/Disciplines. Students from other Departments/disciplines shall take the 6 following GEcourses.)**

STG201T: Introduction to Statistics-I

STG202T: Introduction to Statistics-II

STG303T: Introduction to Probability Theory

STG304T: Introduction to Statistical Inference

STG405T: Introduction to Applied Statistics

STG406T: Introduction to Operations Research

**Skill Enhancement Courses (4 credits each) (Any 2 papers to be selected)**

STS101T: Computational Techniques and R Programming

STS102T: Statistical Techniques for Research Methodology

**Note: The standard statistical software package, viz., R- programming language is introduced in the Semester I as a SEC paper entitled STS 101T: Computational Techniques and R- Programming and also will be used in all the practical courses and projects**

**Syllabi of Core Courses**

**Paper code: STC101T**

**Discriptive Statistics**

**Learning outcomes:**

Students will acquire

- Knowledge of Statistics and its scope and importance in various are as such as Medical, Engineering, Agricultural, Social Sciences, etc.
- Information about various Statistical organisations in India and their functions for societal developments,
- Knowledge of various types of data, their organization and evaluation of summary measures such as measures of central tendency and dispersionet.
- Knowledge of other types of data reflecting quality characteristics including concepts of independence and association between two attributes.

**Contents:**

**Unit I: Statistics and its sources**

**1 credit (13 lectures)**

Introduction to Statistics, Meaning of Statistics as a Science, Importance of Statistics.Scope of Statistics in Industry, Biological sciences, Medical sciences, Economics, Social Sciences, Management sciences, Agriculture, Insurance, Information technology, Education and Psychology.

Statistical Organization in India and their functions:

- Central Statistics Office (CSO) (Definition, organizational structure and functions only)
- Indian Statistical Institute, Calcutta (ISI) Definition and functions only)

- National Sample Survey Organization (NSSO) (Definition, Organizational Structure & present activities only)
- International Institute of Population Studies, Deonar, Mumbai (IIPS) – Definition and functions only.
- Directorate of Economics and Statistics (DES) at the States of India (formally known as Bureau of Economics and Statistics) - Definition, structure and function only.

#### Population and Sample

Notion of a statistical population: Finite population, infinite population, homogeneous population and heterogeneous population. Notion of a sample and a random sample.

#### Measurements and scale:

- Data, Types of data : Quantitative and Qualitative data  
Quantitative : Variables: Interval scale, ratio scale, discrete and continuous variables,  
Qualitative : Attributes – Nominal scale and Ordinal Scale.
- Linear scale and Circular Scale:
- Types of data : (a) Primary data (b) Secondary data (c) Cross-sectional data (d) Time series data and (e) directional data.

#### Presentation of Data:

- Diagrammatic presentation of data : Bar diagram (simple, multiple, sub-divided, percentage), pie diagram, pictogram, cartogram, stem and leaf chart.
- Classification : Raw data and its classification, discrete frequency distribution, continuous frequency distribution, inclusive and exclusive methods of classification, open-end classes, cumulative frequency distribution
- Graphical presentation of frequency distribution : Histogram, frequency curve, frequency polygon, O-give curves,

### Unit II : Measures of Central Tendency & Measures of Dispersion

#### A. Measures of Central Tendency **1 credit (13 lectures)**

- Notion of Central Tendency : Average, characteristics of an ideal average.
- Arithmetic Mean (A.M): Definition, effect of change of origin and scale, combined mean of a number of groups, merits and demerits, its applications.
- Mode: Definition, formula for computation (with derivation), graphical method of Determination of mode, merits and demerits, its applications.
- Median : Definition, formula for computation (with derivation), graphical method of Determination of median, merits and demerits, its applications.
- Empirical relation between mean, median and mode.
- Partition Values : Quartiles, Deciles and Percentiles, their applications.
- Geometric Mean (G.M) : Definition, merits and demerits, its applications
- Harmonic Mean (H.M) : Definition, merits and demerits, its applications
- Relation between A.M., G.M., and H.M.
- Weighted Mean : Weighted A.M., G.M., and H.M.
- Box-plot

#### B. Measures of Dispersion

- Concept of dispersion, characteristics of an ideal measure of dispersion.
- Range : Definition, merits and demerits.
- Semi-interquartile range (Quartile deviation).
- Mean deviation : Definition, merits and demerits, minimality property (without proof).
- Mean square deviation : Definition, , minimality property of mean square deviation (with proof), Variance and standard deviation – definition, merits and demerits, effect of change of origin and scale.
- Determination of variance of a combine series.
- Measures of dispersion for comparison : coefficient of range, coefficient of quartile Deviation and coefficient of mean deviation, coefficient of variation (C.V.)

**Unit-III : Moments, Skewness and Kurtosis****1credit (13 lectures)****A. Moments**

- Raw moments for grouped and ungrouped data.
- Moments about arbitrary constant for grouped and ungrouped data.
- Central moments for grouped and ungrouped data, Effect of change of origin and Scale, Sheppard's correction for moments upto fourth order(without proof).
- Relations between central moments and raw moments (upto fourth order).
- Karl Pearson's  $\beta$  and  $\sqrt{\gamma}$  coefficients

**B. Skewness and Kurtosis**

- Concept of skewness of frequency distribution, positive, negative skewness, symmetric frequency distribution.
- Bowley's coefficient of skewness.
- Karl Pearson's coefficient of skewness
- Measures of skewness based on moments
- Concepts of kurtosis, leptokurtic and platykurtic frequency distributions.
- Measures of kurtosis based on moments

**Unit – IV : Theory of Attributes****1 credit (13 lectures)**

- **Attributes** : classification, notion of manifold classification, dichotomy, class-frequency, order of class, positive class-frequency, negative class frequency, quanta class-frequencies, ultimate class frequency, relationship among different class frequencies (upto three attributes), dot operator to find the relation between frequencies, fundamental set of class frequencies.
- Consistency of data up to 3 attributes), condition for consistency of data.
- Concepts of independence and association of two attributes.
- Yule's coefficient of association (Q)

**Books Recommended**

1. Goon, A.M., Gupta M.K. and Dasgupta, B. (2013) Fundamentals of Statistics, Vol. 1, The World Press Pvt.Ltd., Kolkata.
2. Agarwal, B. L. (2006): Basic Statistics, New Age International Publishers.
3. Kapur, J.N. & Saxena, H.C. (2019) : Mathematical Statistics, S. Chand & Co., New Delhi
4. Medhi, J. (1992): Statistical Methods Wiley Eastern
5. Mukhopadhyay, P. (2016): Mathematical Statistics, New Central Book Agency, Calcutta,
6. Gupta, S.C. and Kapoor, V.K. (2019): Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.

**Course code: STC101P****Practical based on STC101T****2 credits**

**Learning outcomes:** This course is based on STC101T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of ST-C101T. R.programming is introduced in this practical.

**List of Practicals:**

1. R programming, importing and exporting data, R functions, loops, conditional statements, R graphics. ( 2 Practicals)
2. Diagrammatic representation of statistical data problems based on simple multiple and subdivided bar diagrams, pie diagram, pictogram, cartogram, stem and leaf chart (if possible) ( 4 Practicals)
3. Construction of Frequency Distribution and its graphical representation of statistical data. ( 3 Practicals)



4. Computation of measures of central tendency and dispersion. Use of an appropriate measure and interpretation of results. ( 4 Practicals)
5. Moments, Measures of skewness and kurtosis, Box plot. ( 4 Practicals)
6. Consistency of data up to 3 attributes. Concepts of independence and association of two attributes. ( 2 Practicals )
7. Yule's coefficient of association (Q), interpretation. Examples and Problems.(2 Practicals)
8. Calculations of class frequencies based on the given class frequencies. (2 Practicals)

**Books Recommended: Same to recommended books of ST-C101T**

**Course code: ST-C102T Probability Theory-I and Distributions-I**

**Learning Outcomes:**

Students will acquire

- (a) ability to distinguish between random and non-random experiments,
- (b) knowledge to conceptualise the probabilities of events including frequentist and axiomatic approach Simultaneously, they will learn the notion of conditional probability including the concept of Bayes' Theorem,
- (c) knowledge related to concept of discrete random variable and its probability distribution including expectation and moments,
- (d) knowledge of two dimensional r.v.s., its pmf, pdf, df, marginal, conditional probability distribution, identically distributed r.v.s., raw and central joint mgf, and cf
- (e) concept of pairwise independent, transformation of r.v.s. and Jacobian of a transformation.
- (f) Concept of set, set operations, set types, field, sigma-field and measure.

**Contents :**

**Unit – I : Set Theory**

**1 credit (13 lectures)**

- Set types of set, operations on sets and their properties (with proof)
- Intervals- open, closed sets, compact set and their elementary properties.
- Countable and uncountable sets, open and closed sets, compact set and their elementary properties.
- Definition of field of sets, sigma-field and their elementary properties.
- Measure, measure space, elementary properties of measure.

**Unit – II : Probability**

**1 credit (13 lectures)**

- Experiment, Types : Deterministic and Non-deterministic (Random) experiment, concept of Statistical regularity.
- Sample space for discrete, finite and countably infinite.
- Events : Types : (i) Exhaustive, Favourable, Equally likely, Mutually exclusive, independent, certain, uncertain, impossible, (ii) Algebra of events and its representation in set theory notation. Occurrence of following events. (i) at least one of the given events, (ii) none of the given events, (iii) all of the given events, (iv) mutually exclusive events, (v) mutually exhaustive events, (vi) exactly one event out of the given events.
- Probability: Definition – Classical and Statistical (their criticism) and axiomatic.
- Addition theorem and its generalization.
- Elementary properties of probability: i)  $P(\emptyset) = 0$  ii)  $P(A) = 1 - P(A^c)$  iii) If  $A \subseteq B$ , then  $P(A) \leq P(B)$  iv)  $P(A^c \cap B) = P(B) - P(A \cap B)$
- Definition of conditional probability of an event. Definition of independence of two events.

Pairwise independence and mutual independence for three events. Multiplication Theorem and its generalization. Bool's inequality with proof. Related problems.

**Unit – III :Bayesian Probability and Random variable lectures)**

**1 credit (13**

- Bayes' Theorem : Partition of the sample space, Proof of Bayes' theorem, Applications of Bayes' theorem in real life.
- Definition of random variable, Types of random variables – discrete and continuous
- Probability Mass Function (pmf) and its properties,
- Distribution function (df) of a discrete r.v. and its properties, Mode and median of a univariate discrete probability dist<sup>n</sup>.
- Continuous sample space : Definition, illustrations. Continuous random variable: Definition, probability density function (p.d.f.), cumulative distribution function (c.d.f.) properties of c.d.f. (without proof),

**Unit – IV Two-dimensional random variable**

**1 credit (13 lectures)**

Definition of two-dimensional discrete and continuous random variable, joint p.m.f and p.d.f., distribution function and properties, concept of identically distributed r.v.s. Computation of probabilities of events in bivariate probability distribution. Concepts of marginal and conditional probability distributions and its properties (without proof). Definition of raw and central joint moments, Relation between p.d.f. and distribution function.

Independent r.v.'s., pairwise independence and mutual independence for 3 events. Transformation of r.v.'s (upto 2 r.v.'s), Jacobian of a transformation.

**Books Recommended**

1. Goon, A.M., Gupta M.K. and Dasgupta, B. (2013) Fundamentals of Statistics, Vol. 1, The World Press Pvt.Ltd., Kolkata.
2. Agarwal, B. L. (2006): Basic Statistics, New Age International Publishers.
3. Kapur, J.N. & Saxena, H.C. (2019) : Mathematical Statistics, S. Chand & Co., New Delhi
4. Medhi, J. (1992): Statistical Methods Wiley Eastern
5. Mukhopadhyay, P. (2016): Mathematical Statistics, New Central Book Agency, Calcutta,
6. Gupta, S.C. and Kapoor, V.K. (2019): Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.
7. Singh, B. M. (2004): Measure, Probability and Stochastic Processes, South Asian Publishetrs, New Delhi.

**Course code: STC102P**

**Practical based on STC102T**

**2 credits**

**Learning outcomes:** This course is based on STC102T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of ST-C102T. R.programming is introduced in this practical.

**List of Practicals:**

1. Checking whether a given coin is unbiased or not by tossing repeatedly. (1 practical)
2. Checking whether a given die is unbiased or not by rolling repeatedly. (1 practical)
3. Checking whether a given function is a probability function or not (both discrete and continuous case). (4 practicals)
4. To find out the value of distribution function for different values of r.v. from a given univariate probability function (both discrete and continuous case). (4 practicals)
5. To find out median and mode for continuous probability distribution. (3 practicals)
6. To find out the marginal and conditional probabilities from the given joint pdf (continuous case only). (4 practicals)

**Books Recommended: Same to recommended books of ST-C102T**

**Course code: STC103T Statistical methods – I**

**Learning Outcomes:**

Students will acquire

- (a) knowledge related to concept of discrete/ continuous random variable and its probability distribution including expectation and moments,
- (b) knowledge of important discrete distributions such as Binomial, Poisson, Geometric, Negative Binomial and Hyper-geometric and their interrelations if any,
- (c) acumen to apply standard discrete probability distribution to different situations.
- (d) knowledge of correlation of bivariate data, correlation coefficients and its properties.

**Unit –I Expectations**

**1 credit (13 lectures)**

- Mathematical expectation of a r.v. (both discrete and continuous) and its properties  
 $E(a)=a$ , ii)  $E(aX)=a E(X)$ , Addition and Multiplication theorems of expectation,
- Variance and covariance of r.v.'s in terms of expectation, variance and covariance of r.v.'s of linear forms –(i)  $Cov(aX, bY) = ab Cov(X,Y)$  (ii)  $Cov(X+a, Y+b)=Cov(X,Y)$   
(iii)  $Cov[(X-\bar{X})/\sigma_x, (Y-\bar{Y})/\sigma_y] = [1/(\sigma_x\sigma_y)] Cov(X,Y)$  (iv)  $Var(aX)=a^2Var(X)$ , (v) Variance of the sum and variance of the difference of two random variables, (vi) Standardized random variable.

**Unit-II :Generating functions**

**1 credit (13 lectures)**

Theorems on Conditional expectation and conditional variance.

- Moment generating function(mgf) (both discrete and continuous r.v.'s) and its properties-
  - i)  $M_{cx}(t)=M_x(ct)$  ii)  $M_{x_1+x_2+\dots+x_n}(t) = M_{x_1}(t) M_{x_2}(t) \dots M_{x_n}(t)$
  - iii) Effect of change of origin and scale iv) Uniqueness theorem
- Factorial raw moments of univariate probability distributions.
- Inter-relations of raw, central and factorial raw moments (univariate probability distribution).
- Coefficients of skewness and kurtosis based on moments.
- Cumulating generating function and its properties-
  - i) Additive property of cumulants ii) Effect of change of origin on cumulants
- Probability generating function (for discrete r.v) and convolution
- Moments from fusing :i) Expansion method (ii) Differentiation method,
- Relation between moments and cumulants(without proof) upto fourth order
- Characteristic function and its properties (without proof).
- Joint mgf and joint cgf of two dimensional random variables.

**Unit-III : Discrete probability distributions**

**1 credit (13 lectures)**

Some standard discrete probability distributions :

- Bernoulli Trial, Bernoulli distribution
- Binomial distribution and its derivation, Evaluation of its mean, variance, cdf, mgf and cgf, its properties.
- Poisson distribution and its derivation as a limiting case of binomial distribution, Evaluation of its mean, variance, cdf, mgf and cgf, its properties
- Rectangular (uniform) discrete distribution Geometric dist<sup>n</sup>., Negative binomial dist<sup>n</sup>., and Hypergeometric dist<sup>n</sup>, - their means, variance, cdf and mgf.
- Degenerate dist<sup>n</sup>. (one-point dist<sup>n</sup>) and its mean and variance.

**Unit-IV : Correlation****1 credit (13 lectures)**

- Correlation : Bivariate data, scatter diagram and its interpretation, bivariate frequency table and its required terms, difference between bivariate frequency dist<sup>n</sup>. table, correlation table and contingency table concept of correlation between two variables. Interpretation of positive, negative and no correlations.
- Karl Pearson's correlation coefficient (r) : Derivation (ungrouped data) and interpretation Assumptions, Properties : (i) -1 (with proof), ii) Effect of change of origin and scale (with proof)
- Spearman's correlation coefficient : Concept and interpretation, derivation (both in without and with ties), and its limits.

**Recommended Books:**

1. Goon, A.M., Gupta M.K. and Dasgupta, B. (2013) Fundamentals of Statistics, Vol. 1, The World Press Pvt.Ltd., Kolkata.
2. Agarwal, B. L. (2006): Basic Statistics, New Age International Publishers.
3. Kapur, J.N. & Saxena, H.C. (2019) : Mathematical Statistics, S. Chand & Co., New Delhi
4. Medhi, J. (1992): Statistical Methods Wiley Eastern
5. Mukhopadhyay, P. (2016): Mathematical Statistics, New Central Book Agency, Calcutta,
6. Gupta, S.C. and Kapoor, V.K. (2019): Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.
7. Singh, B. M. (2004): Measure, Probability and Stochastic Processes, South Asian Publishers, New Delhi.

**STC103P Practical based on STC103T****2 credits**

**Learning outcomes:** This course is based on STC103T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of ST-C103T.

**List of practicals :**

1. Fitting of Binomial distribution and computation of expected frequencies, mean variance, m.g.f. ( 2 Practicals )
2. Fitting of Poisson distribution and computation of expected frequencies, mean variance, m.g.f. ( 2 Practicals )
3. Fitting of geometric distribution and computation of expected frequencies, mean variance, m.g.f. ( 2 Practicals )
4. Fitting of hypergeometric distribution and computation of expected frequencies, mean variance, m.g.f. . ( 2 Practicals )
5. Fitting of negative binomial distribution and computation of expected frequencies, mean variance, m.g.f. ( 2 Practicals )
6. Experiments based on Karl Pearson's correlation coefficient and Spearman's Rank correlation coefficient. . ( 4 Practicals )

**Recommended Books:** Same to Recommended Books of STC103T

## STC104T: Distributions-II, Estimation-I and Probability Theory

### Learning Outcomes:

After going through this course, the students will get

- (a) Knowledge of some standard continuous distributions, such as Normal, Uniform, Exponential, Cauchy, Beta, Gamma and Weibull distributions and their properties.
- (b) a fundamental understanding of Parametric models for developing relevant inferences on associated parameters,
- (c) knowledge of point and interval estimation procedures and different methods of point estimation,
- (d) knowledge of sampling distributions, laws of large number and central limit theorems,
- (e) to work on several standard examples to help them understand the various inherent concepts.

### Unit – I: Distribution –II

1 credit (13 lectures)

Some standard univariate continuous probability distributions:

- Normal distribution : Definition, Derivation as a limiting case of binomial distribution, mean, median, mode, quartiles, mean deviation, variance, moments, point of inflexion, area properties of normal curve, mgf, characteristic function (including standard normal variable), importance and properties (without proof derivation).
- Uniform dist<sup>n</sup>., Exponential, Cauchy, Beta (both first and second), Gamma (both first and second), Weibuldist<sup>n</sup> : derivation of first two moments and mgf of these distributions.

### Unit – II : Theory of estimation-I

1 credit (13 lectures)

- Concept of parameter and parametric space, random sample, statistic, sampling distribution (only definition)
- Concept of estimation and its problems, estimate, estimator etc.
- Types of estimation: Point and interval estimations
- Criteria of a good estimator- unbiasedness, consistency, sufficiency and efficiency, with simple examples.
- Methods of point estimation- Maximum likelihood estimation (mle), least square, moments and minimum  $\chi^2$ .
- Properties of m.l.e. (without proof), application of the method of m.l.e and method of moments – for obtaining estimates of the parameters of binomial, Poisson and Normal distributions.

### Unit – III : Sampling Distributions.

1 credit (13 lectures)

- Concept of Sampling distribution and Standard error (SE)
- SE of sample mean, proportion, difference of two means, and difference of two proportions (with derivation)
- sampling distribution of sum of binomial and poisson r.v.'s and mean of normal distribution
- sampling distribution of linear function ( $y=a+bx$ ) and square of a normal variate
- for a random sample ( $x_i, i=1,2,\dots,n$ ) drawn from a normal population with mean  $\mu$  and variance  $\sigma^2$  show by using linear orthogonal transformation that

$$\bar{x} \sim N\left(\mu, \frac{\sigma^2}{n}\right), \quad \bar{x} = \text{sample mean and (ii) } \bar{x} = \frac{1}{n} \sum x_i$$

$$\text{and } \frac{ns^2}{\sigma^2} = \sum_{i=1}^n \frac{x_i - \bar{x}}{\sigma}$$

- Derivation of t, F,  $X^2$  distributions, shape of its curves and its properties
- Theorems of  $X^2$  distribution
- Relation between t, F and  $X^2$
- Derivation of sampling distribution of sample total correlation coefficient and sample range.
- Fisher's Z transformation (statement only) and its application.

**Unit - IV : Laws of Large Number & Central Limit Theorems. 1 credit (13 lectures)**

Cauchy-Schwartz (in expectation) and Chebyshev's inequalities and their applications.  
 Convergence in probability, almost sure convergence, convergence in distribution, convergence of mean square.  
 Weak law of large number (Bernoulli and Khinchin) and their applications, Strong Law of Large Number (Statement only)  
 Central limit theorem (iid case) – (De-Moivre- Laplace and Lindeberg-Levy) with illustration  
 And their application to standard distributions.

**Books recommended:**

1. Goon, A.M., Gupta M.K. and Dasgupta, B. (2013) Fundamentals of Statistics, Vol. 1, The World Press Pvt.Ltd., Kolkata.
2. Agarwal, B. L. (2006): Basic Statistics, New Age International Publishers.
3. Kapur, J.N. & Saxena, H.C. (2019) : Mathematical Statistics, S. Chand & Co., New Delhi
4. Medhi, J. (1992): Statistical Methods Wiley Eastern
5. Mukhopadhyay, P. (2016): Mathematical Statistics, New Central Book Agency, Calcutta,
6. Gupta, S.C. and Kapoor, V.K. (2019): Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.
7. Hanagal, D.D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
8. Kendall, M.G. and Stuart, A. (1979). The Advanced Theory of Statistics, Vol. 2. Inference and Relationship. 4<sup>th</sup> Edition. Charles Griffin & Comp.
9. Kendall, M.G., Stuart, A. and Ord, J.K. (1994). The Advanced Theory of Statistics, Vol. 1. Distribution Theory. 6<sup>th</sup> Edition. Halsted Press (Wiley Inc.).

**STC104P Practical based on STC104T**

**2 credits**

**Learning outcomes:** This course is based on STC104T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of ST-C104T.

**List of practicals :**

1. Fitting of Normal distribution and calculation of Expected frequencies. ( 2 Practicals)
2. To find out mgf, characteristic function of a given normal distribution.
3. To find first four moments of a given normal distribution.
4. To find out the points of inflexion of a given normal curve.
5. Drawing graph of the pdf and distribution function and record the mean and variance for a given pdf of uniform distribution.
6. Fitting of exponential distribution and computation of mean, variance and mgf.
7. Application of Beta, Gamma and Weibul distributions.
8. Calculations of the maximum likelihood estimator for binomial, poisson and normal parameters and to obtain variances of these estimates.
9. Calculation of estimators with Minimum Chi-Square and methods of moment.

**Recommended Books:** Same to Recommended Books of STC104T

## **STC205T : Statistical Methods II & Index Numbers**

### **Learning Outcomes:**

This course will acquaint the students with

- (a) knowledge of Standard Normal Variate, its p.d.f, Normal probability plot and q-q plot to test normality
- (b) Various basic concepts on sampling distributions and large sample tests based on normal distribution,
- (c) Small sample tests based on chi-square, Student's and Snedecor's F distributions,
- (d) inferential knowledge regarding the parameters of Bivariate Normal distributions,
- (e) knowledge of Index Number, various method for computing Index Numbers, requirements of good Index Numbers and the construction of Whole Sale and Cost Living Index Numbers.

### **Unit – I : Normal Distribution (continuation)**

**1 credit (13 lectures)**

- Standard normal variable and its pdf
- Pdf curve of normal distributions, identification of scale and location parameters, computations of normal probabilities using normal probability integral tables, additive property, normal probability plot and q-q plot to test normality
- Bivariate normal distribution: Derivation properties, marginal and conditional distributions and related problems.

### **Unit – II : Testing of hypothesis-I**

**1 credit (13 lectures)**

- Statistical hypothesis-simple and composite, null and alternative hypothesis, one and two-tailed test, non-critical and critical region (acceptance and rejection region), level of significance.
- Test of a statistical hypothesis, Type I and II errors, p-value, size of a test, power and power function of test.
- Concept of test of significance, assumptions and their validity
- Large sample test for
  - (i) test of single proportion (ii) test for difference of two proportions (iii) test for single mean
  - (iv) test for difference of two means

### **Unit – 3 : Testing of hypothesis –II**

**1 credit (13 lectures)**

- Application of t-distribution:
  - (i) test for single mean
  - (ii) test for difference of two means (independent and not independent samples)
  - (iii) test for sample correlation coefficient
- Application of F-distribution:
  - (i) test for the equality of two population variances
- Application of  $\chi^2$  distribution:
  - (i) test for population variance  $H_0: \sigma^2 = \sigma_0^2$ .
  - (ii) Test of goodness of fit (1<sup>st</sup> and 2<sup>nd</sup> degree equations, Binomial, Poisson and Normal distributions)

(iii) test of independence of attributes

- Application of Fisher's Z-transformation: To test i) H correlation coefficient
- Variance stabilizing transformations

#### **Unit-IV : Index Numbers**

**1 credit ( 13 lectures)**

- Introduction, problems involved in the construction of index numbers.
- Laspeyre's, Paasche's, Fisher's, Marshall-Edgeworth, Dorbish-Bowley index numbers.
- Requirements of a good index number – time reversal test, factor reversal test and circular Test, Fisher's index number's reversibility.
- Construction of wholesale and cost of living index number.

#### **Books recommended :**

1. Hanagal,D.D.(2009).IntroductiontoAppliedStatistics:A Non-CalculusBased Approach. Narosa Publishing Comp. NewDelhi.
2. Kendall,M.G.and Stuart,A.(1979).The Advanced Theory of Statistics,Vol.
3. Inference and Relationship. 4<sup>th</sup> Edition. Charles Griffin & Comp.
4. Kendall, M.G., Stuart, A. and Ord, J.K. (1994). The Advanced Theory of Statistics, Vol. 1. Distribution Theory. 6<sup>th</sup> Edition. Halsted Press (WileyInc.).
5. Kenney, J.F. and Keeping, E.S. (1947). Mathematics of Statistics. Part I. 2<sup>nd</sup> Edition. Chapman &Hall.
6. Kenney, J.F. and Keeping, E.S. (1951). Mathematics of Statistics. Part II. 2<sup>nd</sup> Edition. Chapman &Hall.
7. Yule,G.U.and Kendall,M.G.(1973).AnIntroduction to the Theory of Statistics. 14<sup>th</sup> Edition. Charles Griffin &Comp.
8. Goon, A.M.,GuptaM.K.and Dasgupta, B.(2013) Fundamentals of Statistics, Vol. 1, The World Press Pvt. Ltd., Kolkata.
9. Agarwal, B. L.(2006): Basic Statistics, New Age International Publishers.
10. Kapur, J.N. & Saxena, H.C. (2019) : Mathematical Statistics, S. Chand & Co., New Delhi
11. Medhi, J. (1992): Statistical Methods Wiley Eastern
12. Mukhopadhyay, P. (2016): Mathematical Statistics, New Central Book Agency, Calcutta,
13. Gupta, S.C. and Kapoor, V.K. (2019): Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.

#### **STC205P: Practical based on STC205T**

**2 credits**

**Learning Outcomes:** This course is based on STC205T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of STC205T.

#### **The list of practical:**

1. Experiment based on Large sample tests: (i) test of single proportion (ii) test for the difference of two proportions (iii) test for single mean and (iv) test for difference of two means. (4 Practicals)
2. Test based on F- distribution – test for the equality of two population variances (1 Practical)
3. Test based on Chi-square distribution (i) Test for equality of population variance (ii) Test of goodness of fit (1<sup>st</sup> & 2<sup>nd</sup> degree) equations, Binomial, Poisson and Normal distributions and (iii) test of independence of attributes. ( 9 Practicals )
4. Test based on Fisher's z – transformation : (i) single sample correlation and (ii) two sample correlations coefficients ( 2 Practicals )
5. Tests based on Laspeyre's, Paasche's, Marshall – Edgeworth, Derbish – Bowley index numbers ( 1 Practical )



6. Test based on Fisher's index number and test for ideal index number (Fisher's index number)  
– Factor reversal and time reversal tests ( 1 Practical )
7. Test based on construction of Wholesale and Cost of Living Index Number. (2 Practicals)
8. Normality probability plot, q-q plot to test normality.

**Books recommended : Same to recommended books of ST-C205T.**

### **STC206T: Statistical Inference-I, Basic Mathematics & Matrices - I**

#### **Learning Outcomes:**

After going through this course, the students will get

- (a) Knowledge of MVUE of different distributions, viz., (i) Binomial, Poisson and normal families,
- (b) Knowledge of interval estimation procedures and procedure of getting confidence interval.
- (c) to understand the Cramer-Rao Inequality, Rao Blackwell and Lehmann Scheffe theorems and their applications in obtaining Minimum Variance Unbiased and Minimum Variance Bound estimators,
- (d) knowledge of convergence of sequence related to infinite series and alternating series,
- (e) knowledge on finding determinant, inverse, rank of a square matrix

#### **Unit –I : Theory of Estimation –II**

**1 credit (13 lectures)**

- Mean square and minimum mean square error estimator,
- Minimum variance estimator (MVE), MVUE and its uniqueness (with proof), MVUE's from the parameters of Binomial, Poisson and Normal families, Cramer-Rao inequality and MVB estimators, lower bound, amount of information, BAN and CAN estimators.

#### **Unit –II : Theory of Estimation –III**

**1 credit (13 lectures)**

- Consistency of estimators and sufficient conditions for consistency, relative efficiency of an estimator, sufficient estimator, factorization theorem for sufficient estimator, concept of complete sufficient statistics, Rao-Blackwell and Lehmann Scheffe theorems (statements only).
- Interval estimation, confidence interval, confidence coefficient (one method of obtaining confidence limits), confidence interval for mean and variance of normal distribution.

#### **Unit - III : Basic Mathematics**

**1 credit (13 lectures)**

- Convergence of sequence, Cauchy criterion
- Infinite series: Cauchy criterion for convergence, geometric series, convergence test of positive term series by (i) comparison test (ii) Cauchy's root test (iii) D'Alembert's ratio test (iv) Raabe's test (application only for the above tests)
- Alternating series: test of convergence (Leibnitz test), concept of absolute convergence, conditional convergence
- Lagrange's method of determining multiplier

- Mean Value Theorem of differential calculus.
- Riemann integrability
- Infinite and improper integral (concept only), Gamma and Beta function and their elementary properties (with proof).

#### **Unit - IV : Determinant and Matrices**

**1 credit (13 lectures)**

Determinants: definition as a function of its element, addition and subtraction, properties (without proof), Minors and co-factors, Matrices- definition, types, addition and multiplication, Adjoint, transpose, determinant of a square matrix., Inverse, rank of a square matrix. Nonsingular matrices and their inverses; determinants of square matrices, elementary row and column operations, ranks, row and column ranks, invariance theorems, Sylvester and Frobenius inequalities; system of homogeneous and non-homogeneous linear equation, their consistency and maximal linearly independent solutions.

#### **Books recommended**

1. Bickel, P.J. and Doksum, K.A. (2000). Mathematical Statistics, Second Edition, Prentice Hall.
2. Casella, G. and Berger, R.L. (2001). Statistical Inference, Second Edition, Cengage Learning.
3. Gupta, M.K., Goon, A.M., and Dasgupta, B. (2013). An Outline of Statistical Theory, Vol. 2. The World Press Publishers Pvt. Ltd., Calcutta.
4. Hogg, R.V., Mc Kean J.W. and Craig, A.T. (2006). Introduction to Mathematical Statistics, Paper back Edition, Pearson.
5. Kale, B.K. (2005). A First Course on Parametric Inference. Alpha Science International Ltd.
6. Mood, A.M., Graybill, F.A. and Boes, D.C. (2011). Introduction to the Theory of Statistics, 3<sup>rd</sup> Edition., (Indian Edition), Tata McGraw-Hill Pub. Co. Ltd.
7. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
8. Rao, C.R. (2009). Linear Statistical Inference and its Applications, Second Edition, Wiley.
9. Singh, B. M. (2008); Introductory Linear Algebra, South Asian Publishers Pvt. Ltd. New Delhi
10. Rohatgi, V.K. and Saleh A.K.M.E. (2008). An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

#### **STC206P: Practical based on STC206T**

**2 credits**

**Learning Outcomes:** This course is based on STC206T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of STC206T.

#### **The list of practical:**

1. Problems based on addition, multiplication, adjoint, transpose, determinant, rank and inverse of square matrices.
2. Evaluation of sufficient statistic for some standard distributions.
3. Consistent estimators, efficient estimators and relative efficiency of estimators.
4. Calculation of MVUE/UMVUE.
5. Calculation of confidence interval/Confidence limits/Confidence coefficient for mean and variance of normal distribution.

**Books recommended : Same to recommended books of ST-C206T.**

## **STC207T: Sampling Techniques& Official Statistics**

### **Learning Outcomes:**

#### **The students shall get**

- (a) basic knowledge of complete enumeration and sample, sampling frame, sampling distribution, sampling and non-sampling errors, principal steps in sample surveys, limitations of sampling etc.,
- (b) introduce to various statistical sampling schemes such as simple, stratified, systematic and pps sampling,
- (c) an idea of conducting the sample surveys and selecting appropriate sampling techniques,
- (d) knowledge about comparing various sampling techniques
- (e) knowledge about various statistical data and records used in the Indian administration.

### **Unit I : Sample Survey –I**

**1 credit (13 lectures)**

- Introduction, concept of statistical population and sample.
- Difference between census and sample survey, advantages of sample survey over census and vice versa.
- Principles of sampling theory – validity, regularity and optimization.
- Principle steps involved in a large scale sample survey, preparation of questionnaire and schedule, sampling and non-sampling errors.
- Some sampling techniques concept of purposive, quota, snowball and volunteer sampling.
- Simple random sampling (with and without replacement): Notations and terminology, probabilities of selection techniques of selecting a random sample – lottery method & use of Random Number Tables, estimation of population total and mean, variance and S.E. of the estimates, unbiasedness of sample mean for the population mean, merits and demerits, comparison of simple random sampling with and without replacement.
- Simple random sampling of attributes
- Determination of sample size for (i) specified coefficient of dispersion, and (ii) given margin of error in estimate and the confidence coefficient.

### **Unit – II : Sample Survey-II**

**1 credit (13 lectures)**

- Probability proportional to size (PPS) sampling-Definition and terminology, cumulative total method and Lahiri's methods of selecting PPS sampling with and without replacement.
- Stratified random sampling: definition of strata, advantage of stratification principles of stratification, estimation of population total and mean, variance and SE of its estimates, allocation of samples: (i) equal (ii) proportional (iii) Neyman (optimum), derivation of the variances for proportional and optimum allocation.
- Gain in precision due to stratification: proportional and optimum in comparison with SRS.

### **Unit – III : Sample Survey – III**

**1 credit (13 lectures)**

- Systematic sampling (linear): techniques of selecting systematic sample, merits and demerits, estimation of population total and population mean and its sampling variance, comparison of systematic sampling with simple random sampling and stratified sampling
- Systematic sampling (circular): Concepts and examples.
- Techniques of : Cluster sampling Two stage and multi-stage sampling, multiphase sampling, double sampling

- Comparison of multistage and multiphase sampling

#### **Unit – IV : Indian Official Statistics**

**1 credit (13 lectures)**

- Statistical system in India, CSO (Central Statistical Office) NSSO, Office of the Registrar General, Directorate-General of Commercial Intelligence and Statistics, Directorate of Economics and Statistics(in states) Labour Bureau, Army Statistical Organisation (features of the organizations and name of their publications only)
- Discussion on the official statistics of India related to census, agriculture and industries,
- Census types of census and type adopted by India, organization of census, type of data included in the schedule of 1st census.
- Agricultural Statistics- Land utilization statistics, total area, classification of area, area under crop, area irrigated, crops irrigated, crop production statistics-forecast crops, non-forecast and plantation crops
- Industrial statistics- Statistics relating to organized and unorganized sectors.
- Study of official publications and journals of North Eastern Council (NEC) and Basic Statistics of NEC.

#### **STC207P: Practical based on STC207T**

**2 credits**

**Learning Outcomes:** This course is based on STC207T and will provide practical knowledge to the students on various concepts elaborated in the course. The learning outcomes of the course is similar to that of STC207T.

##### **The list of practical:**

1. Simple Random Sampling- Lottery, Random number method and other related problems.
2. Probability Proportional to Size Sampling: Cumulative total method and Lahiri's method.
3. Systematic Sampling – Problems related to Linear and Circular systematic sampling.
4. Problems related to Systematic sampling and Linear Trend.
5. Stratified Random Sampling- Problems related to Different types of allocation.
6. Stratified Random Sampling- Problems related to Optimum allocation and other related problems.
7. Sample size calculations.
8. Estimation of Mean and Variance in Cluster sampling.

**Books recommended : Same to recommended books of ST-C207T.**

#### **STC208T : Regression Analysis**

##### **Learning Outcomes :**

The students shall

- (a) Know about correlation and regression techniques, the two very powerful tools in statistics,
- (b) get an idea of Linear, Polynomial and Multiple Linear regression,
- (c) learn about regression diagnostics, multicollinearity, residual plots and estimation and tests for regression coefficients.
- (d) Study concept of coefficient of determination and inference on partial and multiple correlation coefficients.

## Contents:

### Unit – I Curve fitting

1 credit (13 lectures)

- Concept of curve fitting
- Method of least square, most plausible values
- Fitting of polynomials (1<sup>st</sup> and 2<sup>nd</sup> degree) by least squares method
- Fitting of polynomials by orthogonal polynomials : Importance of using orthogonal polynomials in curve fitting and derivation of orthogonal polynomials.

### Unit – II : Correlation

1 credit (13 lectures)

- Multiple and partial correlation(for three variables), their coefficients and properties, residual and its properties, variance of residuals.
- Multiple and partial correlation coefficient in terms of total correlation coefficients for 3 variables.
- Explained and unexplained variation, coefficient of determination.
- Intra class correlation coefficient (derivation) and its limits.
- Correlation ratio (derivation) and its properties.
- Pearsonian system of curve- Pearsonian general differential equation and derivation of Pearsonian curves of Type-I II and III.

### Unit – III : Regression Analysis –I

1 credit (13 lectures)

Linear Regression: Meaning of regression, difference between correlation and regression, simple linear regression model, Estimation of regression parameters by least squares method (fitting of regression model), Interpretation of parameters. Concept of residual, Residual plots, comparison of two models on the basis of residual sum of squares, Regression diagnostics, Tests for regression diagnostics. Tests for regression coefficients.

### Unit –IV : Regression Analysis-II

1 credit (13 lectures)

Multiple linear regression: Estimation of regression parameters by least square method, Interpretation of parameters, Concept of coefficient of determination. Multicollinearity. Inference on partial and multiple correlation coefficients., Test of departure from normality assumption, detection of outliers, test for homogeneity of variance, departure from Gauss-Markov set up, heteroscedasticity, autocorrelation.

## Recommended Books:

1. Draper, N.R. and Smith, H. (1998). Applied Regression Analysis. 3<sup>rd</sup> Edition. John Wiley.
2. Hosmer, D.W., Lemeshow, S. and Sturdivant R.X. (2013). Applied Logistic Regression, Wiley Blackwell.
3. Montgomery, D.C., Peck, E.A. and Vining, G.G. (2013). Introduction to Linear Regression Analysis. 5<sup>th</sup> Edition. Wiley.
4. Neter, J., Kutner, M.H., Nachtsheim, C.J. and Wasserman, W. (1996). Applied Linear Statistical Models, 4<sup>th</sup> Edition, Irwin USA.

## STC208P: Practical based on STC208T

2 credits

### Learning Outcomes:

The students shall be

- (a) able to use demonstrate knowledge of different numerical methods, essential for providing Mathematical support to the Statisticians where intractability becomes severe,
- (b) be able to forecast numerical phenomenon, using Bisection, Newton Raphson, Regula Falsi Methods,

- (c) be able to find solutions to difference equations of first order and linear difference equations with constant coefficients and apply regression techniques, obtain UMP tests and demonstrate knowledge of numerical methods
- (d) able to find out the relationship of variables by using different correlation coefficients
- (e) able to fit linear and multiple regression lines or curves to the given data and draw conclusion
- (f) able to determine the distribution of a given frequency distribution by using Pearsonian type-I, II and III curves.

**List of the practicals:**

1. Calculation of coefficient of intra class correlation and correlation ratio.
2. Simple linear regression, residuals, estimate of intercept, regression coefficients.
3. Residual plots, regression diagnostics.
4. Multiple linear regression and regression estimates.
5. Calculation of multiple correlation,
6. Calculation of partial correlation.
7. Fitting of 1<sup>st</sup> and 2<sup>nd</sup> degree equations by (i) least square method and (ii) orthogonal polynomials.
8. Fitting of Pearsonian type I, II and III curves.

**Books recommended : Same to recommended books of ST-C208T.**

**STC 209T : Statistical Inference –II**

**4 credits**

**Learning Outcomes :**

The course will provide the students with a knowledge of

- (a) Advanced level topics in statistical inference on testing of statistical hypotheses for both randomized and non-randomized tests,
- (b) Using Neyman Pearson Lemma and finding Uniformly Most Powerful Test,
- (c) likelihood ratio test and its applications,
- (d) confidence interval estimation and their relationships with testing,
- (e) order statistics and their distributions,
- (f) Wald's Sequential Probability Ratio Test and concepts of ASN and OC functions,
- (g) Sequential estimation with examples based on standard probability distributions,
- (h) Statistical decision problem including the concept of loss and risk functions, Bayes and Minimax Decision rules.

**Unit –I : Testing hypothesis –III 1 credit (13 lectures)**

- Review of Statistical hypothesis, critical region, size and power of a test,
- Most powerful test and Most powerful critical region (MPCR), Neyman-Pearson lemma and its application in construction of MPCR for testing simple hypothesis against simple alternative for binomial, Poisson and normal distributions.

**Unit –II : Testing of hypothesis- IV & order statistics 1 credit (13 lectures)**

- UMPCR, unbiased test, UMPUCR
- Definition of order statistics-derivation of the distribution of  $r$ th sample order statistic joint distribution of  $r$ th and  $s$ th sample order statistics and distribution of range.

**Unit –III : Sequential Analysis 1 credit (13 lectures)**

- Sequential Analysis: Need for sequential tests. Wald's SPRT, ASN, OC FUNCTION. Brief idea of sequential estimation, examples based on normal, Poisson, binomial and exponential distributions.

**Unit – IV :Decision Theory I 1 credit (13 lectures)**

- Elements of decision theory, decision problems: Formulation of Decision Problem, expected loss and risk function, Non-randomized and randomized decision rules, estimation and testing viewed as decision problems and its examples, decision principles, Bayes and Minimax, least favourable distribution, Bayesian analysis, conjugate families of prior distributions, posterior decision analysis, forms of Bayes rules for estimation and testing problem.

**Recommended Books :**

- Gibbons, J. D (1971): Non-Parametric Statistical Inference, Mc Graw-Hill Book Company.
- Casella, G. and Berger, R. L. (2001). Statistical Inference, Second Edition, Cengage Learning.
- D'Abbrera H. J. M. and Lehmann, E. L. (2006). Non-parametrics: Statistical Methods Based on Ranks. Prentice Hall.
- Gupta, M. K., Gun, A. M., and Dasgupta, B. (2013). An Outline of Statistical Theory, Vol. 2. The World Press Publishers Pvt. Ltd., Calcutta.
- Kale, B. K. (2005). A First Course on Parametric Inference. Alpha Science International Ltd.
- Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
- Rao, C. R. (2009). Linear Statistical Inference and its Applications, Second Edition, Wiley.

**STC209P: Practical based on STC209T 2 credits**

**Learning Outcomes:**

The students shall be

- (a) able to use demonstrate knowledge of different numerical methods, essential for providing Mathematical support to the Statisticians where intractability becomes severe,
- (b) be able to forecast numerical phenomenon, using Bisection, Newton Raphson, Regula Falsi Methods,
- (c) be able to find solutions to difference equations of first order and linear difference equations with constant coefficients and apply regression techniques, obtain UMP tests and demonstrate knowledge of numerical methods

- (d) able to find out the relationship of variables by using different correlation coefficients
- (e) able to fit linear and multiple regression lines or curves to the given data and draw conclusion
- (f) able to determine the distribution of a given frequency distribution by using Pearsonian type-I, II and III curves.

**List of the practicals:**

1. Calculation of Type I and Type II error probabilities.
2. Calculation of size of critical region, power of the test for the mean of a normal distribution with known and unknown variance and plotting graph of the power function.
3. Calculation of size of most powerful critical region (NP lemma).
4. Calculation of power of the test for the Bernoulli distribution with probability (p) in case of simple hypothesis and power curves and plotting the graph of the power function.
5. Sequential probability ratio test for the given hypothesis, esp. For Bernoulli trials. Calculation of ASN and OC curve.

**Books recommended : Same to recommended books of ST-C209T.**

**STC 210T : Numerical Analysis**

**4 credits**

**Learning Outcomes:**

The students shall

- (a) Demonstrate knowledge of different numerical methods, essential for providing Mathematical support to the Statisticians where intractability becomes severe,
- (b) be able to learn various difference, interpolation formulae,
- (c) be in a position to find solutions to equations using Bisection, Newton Raphson and Regula Falsi Methods,
- (d) handle numerical differentiation and integration,
- (e) be able to find solutions to difference equations of first order and linear difference equations with constant coefficients.
- (f) be able to forecast numerical phenomenon.

**Unit –I : Finite Difference –I**

**1 credit (13 lectures)**

- Basic concept of finite difference theory
- Operators-  $\Delta$  and  $E$  and their relations, construction of diagonal and horizontal difference tables, determination of the values of  $n$ th and  $(n+1)$ th degree difference of the polynomial of degree  $n$  (Theorem with proof).



**Unit – II : Finite Difference – II****1 credit (13 lectures)**

- Concept of interpolation and extrapolation and their importance, derivation of
- Newton's forward and backward interpolation formula (without remainder terms),
- Construction of divided difference table and its properties, Newton's divided difference interpolation formula and Lagrange's interpolation formula for unequal intervals (without remainder terms)
- Central difference formulae : Gauss and Stirlingi formulae.

**Unit –III : Finite Difference – III****1 credit (13 lectures)**

Inverse interpolation : Lagrange's inverse interpolation formula, Method of successive approximation and method of reversion of series Stirling's bivariate interpolation. Finding root of an Equation: Bisection, Regula Falsi and Newton Raphson Methods. Numerical differentiation.

**Unit – IV : Finite Difference – IV****1 credit (13 lectures)**

Numerical integration: Newton-Cote's integration formula, Trapezoidal rule, Simpson's one-third rule, Simpson's three-eight rule and Weddle's rule with error term, Euler-Maclaurin's summation formula. Stirling's approximation to factorial n. Laplace- Everett Solution of difference equation with constant coefficients (homogeneous, non-homogeneous equations only)

**Recommended Books:**

1. Bradie,B.(2006). A friendly introduction to Numerical Analysis, Pearson Education, India.
2. Gerald,C.F.and Wheatly,P.O.(2005).Applied Numerical Analysis, Pearson Education, India.
3. Hilderbrand,F.B.(1987).Introduction to Numerical Analysis, Second Edition, Dover Publications.
4. Jain,M.K.,Iyengar,S.R.K.andJain,R.K.(2007).Numerical Methods for Scientific and Engineering Computation, Second Edition, Wiley Eastern Ltd.
5. Krishnamoorthy,E.V.and Sen,S.K.(2001).Numerical Algorithms:computations in Science and Engineering. East West Press, NewDelhi.
6. Sastry,S.S.(2000).Introductory Methods of Numerical Analysis, 3<sup>rd</sup> edition, Prentice Hall of India Pvt. Ltd., New Delhi.
7. Saxena,H.C.(2005).Finite Differences and Numerical Analysis, 15<sup>th</sup> Revised Edn. (Reprint). S. Chand &Co.
8. Scarborough,J.B.(1966).Numerical Mathematical Analysis, 6<sup>th</sup> Edition. Oxfordand IBH.

**STC210P: Practical based on STC210T****2 credits****Learning Outcomes:**

The students shall be

- (a) able to use demonstrate knowledge of different numerical methods, essential for providing Mathematical support to the Statisticians where intractability becomes severe,
- (b) be able to forcast numerical phenomenon, using Bisection, Newton Raphson, Regula Falsi Methods,
- (c) be able to find solutions to difference equations of first order and linear difference equations with constant coefficients and apply regression techniques, obtain UMP tests and demonstrate knowledge of numerical methods
- (d) able to findout.the relationship of variably by using different correlations coefficients

- (e) able to fit linear and multiple regression linear or curves to the given data and draw conclusion
- (f) able to determine the distribution of a given frequency distribution by using pearovian type-I,II and III curves.

**List of the practicals:**

1. Newton's forward, backward and divided difference interpolation formulae with error term.
2. Lagrange's interpolation formula, Central difference formulae.
3. Lagrange's inverse interpolation.
4. Trapezoidal rule, Simpson's one-third rule and Simpson's three-eighth rule.
5. Weddle's rule with error term.
6. Stirling's approximation to factorial  $n!$ .
7. Euler-Maclaurin's summation formula.
8. Solution of difference equations of first order with variable coefficients and linear difference equations with constant coefficients.
9. Finding root of equations: Bisection, Regula Falsi and Newton Raphson methods.

**Books recommended : Same to recommended books of ST-C210T.**

**STC311T : Optimisation Techniques:**

**4 credits**

**Learning Outcomes:**

The students shall get exposed to

- (a) Graphical and simplex method of solving linear programming problem (LPP) for finding degenerate, unbounded, alternate and infeasible solutions,
- (b) Post-optimality: addition of constraints, change in requirement vector, addition of new activity and change in cost vector,
- (c) Use of duality to solve a LPP,
- (d) Obtaining solution of a transportation problem by North West corner method, Matrix Minima method, Vogel's method,
- (e) Hungarian Method for solving assignment problems,
- (f) Game theory for graphical solution of  $m \times 2$  or  $2 \times n$  rectangular game and mixed strategy,
- (g) Networking problem using minimal spanning tree and shortest route,
- (h) Optimal inventory policy for EOQ model and its variations.
- (i) Solving quantity discounts model with price breaks.

**Unit –I : Operation Research –I** **1 credit (13 lectures)**

Origin and development of OR, importance and scope of OR

- Models of OR – iconic analogue and mathematical models – their construction and general method of solution
- Elements of LPP canonical and standard forms formulation of IPP
- Solution of LPP by graphical method (for 2 variables).

**Unit –II : Operation Research –II** **1 credit (13 lectures)**

- Solution of LPP by simplex method
- Artificial variable, solution of LPP by Big-M method
- Concept Principle and formulation of dual problem, statement and proof of duality theorem
- Dual simplex method, simple problems based on duality theorem.

**Unit –III : Operation Research –III** **1 credit (13 lectures)**

Allocation Models: Transportation problem (T.P.), different methods of finding initial feasible solution of a T.P., UV method of finding optimal solution of a T.P., solution of assignment problem using Hungarian method.

**Unit –IV : Operation Research –IV** **1 credit (13 lectures)**

Inventory Control: Definitions of various costs involved in inventory control. ABC inventory system, characteristics of inventory system.

Theory of games: Two person zero-sum games, pure and mixed strategies, saddle point, minimax-Maximin principle of rectangular games, games with and without saddle point.

**Recommended Books:**

1. Gass, S.I. (2010). Linear Programming, Methods and Applications, 5<sup>th</sup> Ed., Dover Books.
2. Hadley, G. (2002). Linear programming. Narosa.
3. Hiller, F.S. and Lieberman, G.J. (2009). Introduction to Operations Research, McGrawHill.
4. McKinsey, J.C.C. (2003). Introduction to the Theory and Games. Dover Books.
5. Swaroop, K., Gupta, P.K. and Singh, M.M. (2005). Operations Research. Sultan Chand and Sons.
6. Taha, H.A. (2014). Operations Research, Ninth Edition, Pearson Education India.

**STC311P: Practical based on STC311T****2 credits****Learning Outcomes:**

- (a) This course is based on **STC311T** and at the end of the course, students shall be able to draw different types of control charts for variables and attributes. They will also be able to understand the practical applicability of single and double sampling inspection plans.
- (b) The students will be able to get an idea of reliability and hazard function and how to discriminate among the important lifetime distributions based on hazard function.
- (c) The students shall be able to deal Scores with T-Scores and percentile Scores
- (d) The students shall be able to solve problems by using methods relative to allocation models, Inventory control, etc.

**List of practicals:**

1. Graphical and simplex method of solving linear programming problem (LPP) for degenerate solution, unbounded solution, alternate solution and infeasible solution.



**Unit – IV : Psychological & Educational Statistics    1 credit   (13 lectures)**

- Scale, characteristics of a scale, Assumptions in scaling
- Scaling of test items : Scaling individual test items in terms of difficulty, difficulty value of a test items and problems based on this.
- Scaling of scores on a test score, raw score, scaled score, standard scores, normalized scores, T-scores, percentile scores and problems based on them.
- Scaling of rankings and ratings in terms of normal probability curve,
- Reliability of test scores: Concept of reliability, Linear model of modern test theory and its components and assumption, index of reliability, parallel test.
- Methods of determining test reliability : Test-relist, alternate or parallel form, split-half and Rational equivalence or Kuder-Rechardson.
- Test length on reliability : Spearman – Brown prophecy formula to determine reliability for a given test length, lengthening a test to achieve a certain desired reliability
- Validity: Concept of validity of test scores, validity and test length, lengthening needed to achieve given validity.
- Intelligence Quotient (IQ) : IQ in terms of mental and chronological ages, classification of individuals based on IQ level according to StandforBinet 5<sup>th</sup> edition classification, Terman classification and Merrill classification (only classification tables).
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**Recommended Books:**

- Banks,J.(1989).Principles of Quality Control. John Wiley & Sons, New York.
- Barlow,R.E.andProschan,F.(1974).Statistical Theory of Reliability and Life Testing Probability Models, Holt Rinehart andWinston.
- Duncan,A.J.(1974).QualityControl and Industrial Statistics, 4<sup>th</sup> Edition, Taraporewala&Sons.
- Montgomery, D.C. (2012). Introduction to the Statistical Quality Control, 7<sup>nd</sup> Edition, John Wiley &Sons.
- Schilling,E.G.andOtt,E.R.(1975).Process Quality Control. McGrawHill.

**STC312P: Practical based on STC312T****2 credits****Learning Outcomes:**

- (e) This course is based on **STC312T** and at the end of the course, students shall be able to draw different types of control charts for variables and attributes. They will also be able to understand the practical applicability of single and double sampling inspection plans.
- (f) The students will be able to get an idea of reliability and hazard function and how to discriminate among the important lifetime distributions based on hazard function.
- (g) The students shall be able to deal Scores with T-Scores and percentile Scores
- (h) The students shall be able to solve problems by using methods relative to allocation models, Inventory control, etc.

**List of practicals:**

1. Construction of controlcharts: $\bar{X}$ -chart,p-chart, np-chart, c-chart, V-chart etc.
2. Draw R chart and modified R chart.
3. Computation of MLE of exponential, lognormal distributions.
4. Computation of MLE of exponential distribution for censored data.
5. Computation of MLE of Gamma and Weibull distributions using iterative procedure.
6. Fitting of Exponential and Weibull distributions for a given lifetime data set.

7. Plotting of Survival function and hazard rate function for exponential, Weibull, Gamma and lognormal distributions.
8. T-Score and Percentile Score.

**Recommended Books:** Same to Recommended books of STC312T

### **STC313T: Design of Experiments**

**4 credits**

#### **Learning Outcomes :**

The students will be in a position to

- (a) carry out one way and two way Analysis of Variance (ANOVA).
- (b) understand the basic terms used in design of experiments,
- (c) use appropriate experimental designs to analyze the experimental data,  $2^2$ ,  $2^3$ , &  $2^4$  factorial experiments.
- (d) analyze :  $2^2$ ,  $2^3$  and  $2^4$  factorial experiments,
- (e) apply Multiple range test, the LSD test or the multiple t-test, Student-Newman-Keuls test, Duncan's multiple range test, Tukey's test, Multiple F tests, Fisher's least significant difference test, Scheffe's tests,
- (f) give statistical interpretation of the experimental results obtained.

#### **Contents:**

##### **Unit I : Analysis of Variance**

**1 credit (13 lectures)**

Analysis of variance: Definition, assumption for ANOVA test, one-way and two-way classifications for fixed effect model with one observation per cell. Introduction to design of experiments: terminology, experiments, treatment, experimental units, blocks, experimental error, replication, precision and accuracy, need for design of experiment, size and shape of plots and blocks.

##### **Unit –II :Some Designs of Experiments**

**1 credit (13 lectures)**

Fundamental principles of design of experiments: Randomization, Replication and Local control, Completely randomized design (CRD), Randomized Complete Block Design(RCBD), Latin square design(LSD) and their layout and analyses. Missing plot technique for RCBD and LSD : missing plot techniques for one and two observation per cell in RCBD and one observation per cell in LSD. Analysis of covariance in CRD and RCBD with one concomitant variable: concepts and examples, transformations.

##### **Unit III : Comparison Tests**

**1 credit (13 lectures)**

Multiple range tests, the LSD test, Student-Newman-Keuls test, Duncan's multiple range test, Tukey's test, comments on multiple range test, Multiple F tests, Fisher's least significant difference test, Scheffe's test, comments on multiple F tests.

##### **Unit IV : Factorial Experiments**

**1 credit (13 lectures)**

- Factorial experiments: Definition, advantages and limitations, main effects and interaction effects, concepts and analysis of  $2^2$ ,  $2^3$ , and  $2^4$  factorial experiments applied in RBD.
- Yate's procedure for computation of factorial effect totals and their analyses.
- Analysis of  $2^2$ ,  $2^3$  and  $2^4$  factorial experiments applied in RBD.
- Concept of  $3^2$  and  $3^3$  factorial experiment (without analysis)
- Confounding in factorial experiments (Total and partial confounding in  $2^2$ ,  $2^3$  and  $2^4$ .)
- Concept of confounding in  $3^2$  and  $3^3$  factorial experiment (layout only)
- Split plot technique applied in RBD (without analysis)
- Description of strip plot arrangement in RBD (without analysis)
- Series of experiment (without analysis).

**Recommended Books:**

1. Cochran, W.G. and Cox, G.M. (1957). Experimental Design. John Wiley & Sons, New York.
2. Das, M. N. and Giri, N. S. (1986). Design and Analysis of Experiments (2<sup>nd</sup> Edition). Wiley.
3. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments. Springer-Verlag, New York.
4. Federer, W.T. (1955). Experimental Design: Theory and Applications. Oxford & IBH Publishing Company, Calcutta, Bombay and New Delhi.
5. Joshi, D.D. (1987). Linear Estimation and Design of Experiments. New Age International (P) Ltd. New Delhi.
6. Montgomery, D.C. (2017). Design and analysis of Experiments, 9<sup>th</sup> Edition. John Wiley & Sons.

**STC313P : Practical based on STC313T****2 credits****Learning Outcomes:**

The student shall be able to analyse data using various non-parametric tests. Also, the students will be in a position to visualize the scope of experimental designs in getting valid and efficient results. As a result, they will decide to select an appropriate experimental design and analyse the same to interpret the results so obtained.

**List of Practicals**

1. ANOVA for one-way & two way classifications (2 Practicals)
2. CRD, RBD, LSD (3 Practicals)
3. Missing plot techniques for RBD and LSD (3 Practicals)
4. Factorial experiments – 2<sup>2</sup>, 2<sup>3</sup> and 2<sup>4</sup> Factorial experiments applied in RBD (3 Practicals)
5. Confounding in Factorial experiments (total and partial) in 2<sup>2</sup>, 2<sup>3</sup>, and 2<sup>4</sup> experiment (3 Practicals)
6. Experiments based on comparison tests.

**Recommended Books :**

1. Cochran, W.G. and Cox, G.M. (1957). Experimental Design. John Wiley & Sons, New York.
2. Das, M. N. and Giri, N. S. (1986). Design and Analysis of Experiments (2<sup>nd</sup> Edition). Wiley.
3. Federer, W.T. (1955). Experimental Design: Theory and Applications. Oxford & IBH Publishing Company, Calcutta, Bombay and New Delhi.
4. Montgomery, D.C. (2017). Design and analysis of Experiments, 9<sup>th</sup> Edition. John Wiley & Sons.
5. Gibbons, J.D. and Chakraborty, S. (2010). Nonparametric Statistical Inference, Chapman and Hall/CRC.
6. Sheskin, D.J. (2011). Handbook of Parametric and Nonparametric Statistical procedure. (Fifth Edition), Chapman and Hall/CRC.
7. Siegel, S.J. and Castellan, N.Jr. (1998). Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill.

8. Wayne, W. D. (2000). Applied Nonparametric Statistics, 2<sup>nd</sup> Edition. Cengage Learning.

**STC314T: Non-Parametric Inference 4 credits**

**Learning Outcomes:**

This course will help the students to

- (a) use different non-parametric/distribution-free tests when data don't meet the assumptions of parametric test,
- (b) understand importance of different non-parametric test procedures, their applications and interpretation,
- (c) analyse categorical data using logistic regression models.

**Contents:**

**Unit I : One Sample Tests 1 credit (13 lectures)**

Introduction, concepts of non-parametric/distribution free method: one-sample case: Binomial test, Chi-Square Goodness-of-fit test, Kolmogorov-Smirnov one sample test, One-sample runs test for randomness, sign test, Wilcoxon's signed rank test, theory and applications.

**Unit II : Two Sample Tests 1 credit (13 lectures)**

Two-sample case: median test, Wilcoxon-Mann-Whitney test, Mood test, Freund-Ansari test, Kolmogorov-Smirnov two-sample test, Siegel-Tukey test for scale differences, theory & applications.

**Unit III : Multi-Sample Tests. 1 credit (13 lectures)**

The Cochran Q test for K related samples: Friedman test by ranks, extended median test, Kruskal-Wallis one-way analysis of variance by ranks, Jonckheere test for ordered alternatives. Theory and applications of these tests.

**Unit IV : Categorical Data Analysis 1 credit (13 lectures)**

Concept of Indicator Variables, categorical data analysis, logistic regression models, models with binary response. Theory and Applications.

**Recommended Books :**

1. Gibbons, J.D. and Chakraborty, S. (2010). Nonparametric Statistical Inference, Chapman and Hall/CRC.
2. Kloeke, J. and McKean, J.W. (2014). Nonparametric Statistical Methods Using R. Chapman & Hall/CRC Press.
3. Neuhauser, M. (2017). Nonparametric Statistical Tests. A Computational Approach, Chapman and Hall/CRC.
4. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
5. Sheskin, D.J. (2011). Handbook of Parametric and Nonparametric Statistical procedure. (Fifth Edition), Chapman and Hall/CRC.
6. Siegel, S., J. and Castellan, N. Jr. (1998). Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill.
7. Sprent, P. and Smeeton, N.C. (2007). Applied Nonparametric Statistical Methods, Chapman & Hall/CRC Press.
8. Wayne, W. D. (2000). Applied Nonparametric Statistics, 2<sup>nd</sup> Edition. Cengage Learning.



**STC314P : Practical based on STC314T****2 credits****Learning Outcomes:**

The student shall be able to analyse data using various non-parametric tests. Also, the students will be in a position to visualize the scope of experimental designs in getting valid and efficient results. As a result, they will decide to select an appropriate experimental design and analyse the same to interpret the results so obtained.

**List of Practicals**

1. Non-parametric tests: (i) One sample test, Binomial test, Chi-square goodness of fit test, Kolmogorov – Smirnov test, run test for randomness, sign test, Wilcoxon Signed Rank Test, etc. ( 6 Practicals )
2. Two-Sample Case – Median test, Wilcoxon-Mann-Whitney U-test, Mood test, Freund- Ansari test, Kolmogorov – Smirnov two-sample test, Siegel-Tukey test for scale differences ( 5 Practicals)
3. The Cochran Q test for k related samples, Friedman test by ranks, extended median test
4. Kruskal-Wallis One-Way Analysis of variance by ranks.
5. Jonckheere test for ordered alternatives.
6. Logistic Regression Model fitting (using 3/4 independent variables).

**Recommended Books :**

1. Cochran, W.G. and Cox, G.M. (1957). Experimental Design. John Wiley & Sons, New York.
2. Das, M. N. and Giri, N. S. (1986). Design and Analysis of Experiments (2<sup>nd</sup> Edition). Wiley.
3. Federer, W.T. (1955). Experimental Design: Theory and Applications. Oxford & IBH Publishing Company, Calcutta, Bombay and New Delhi.
4. Montgomery, D.C. (2017). Design and analysis of Experiments, 9<sup>th</sup> Edition. John Wiley & Sons.
5. Gibbons, J.D. and Chakraborty, S. (2010). Nonparametric Statistical Inference, Chapman and Hall/CRC.
6. Sheskin, D.J. (2011). Handbook of Parametric and Nonparametric Statistical procedure. (Fifth Edition), Chapman and Hall/CRC.
7. Siegel, S.J. and Castellan, N.Jr. (1998). Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill.
8. Wayne, W. D. (2000). Applied Nonparametric Statistics, 2<sup>nd</sup> Edition. Cengage Learning.

**STC415T : Real analysis & Statistical Inference-III****4 credits****Learning Outcomes:**

Students will acquire specific knowledge on

- Real number system, fields of numbers,
- Metric space, sequences and series,
- Continuity and differentiability of functions.



**List of practicals:**

- 1) Determination of admissible decision rule
- 2) Finding of Bayes action
- 3) Finding of minimax solution
- 4) Finding of Bayes decision rule with given prior distribution
- 5) Construction of posterior distribution
- 6) Finding of Bayes estimator
- 7) Determination of maximin and minimax strategies

**Books recommended: Same to recommended books of ST-C415T.**

**STC416T :Linear Algebra, Matrices-II& Measure Theory I****4 credits****Learning Outcomes:**

Students will acquire knowledge on

- Vector spaces, linear transformation and projections,
- Matrix algebra and determinants of matrices,
- Characteristics polynomials and solution of system of linear equations.
- Basic elements of decision theory, Randomized and non-randomized decision functions
- Bayesian analysis
- Minimax analysis, solving statistical games, two person zero sum game.

**Unit I:Linear Algebra                      1 credit (13 lectures)**

Vector spaces over fields of scalars, linear independence of vectors, dimension and bases for finite dimensional vector spaces, orthogonality of vectors and subspaces, Gram – Schmidt theorem, linear transformations and projections and their representations by matrices.

**Unit II:Matrices I                                      1 credit (13 lectures)**

Row, column spaces of matrix, of product matrix and their dimensions; row, column rank and rank of a matrix, theorems on row, column rank and rank of a matrix; relationship among columns numbers, rows numbers and rank; Sylvester Theorem, Characteristics polynomials of a square matrix, latent roots, vectors and their calculations, relation between algebraic and geometric roots; Cayley-Hamilton theorem, similarity and diagonalization of square matrices,.

**Unit III:Matrices II                                      1 credit (13 lectures)**

System of homogeneous linear equations, System of non-homogeneous linear equations, their basic solutions. Necessary and sufficient conditions for their consistency; minimal polynomial of a square matrix, relation between latent roots and determinant of a square matrix, quadratic forms and their value classes, canonical reductions of quadratic forms, simultaneous reducibility of quadratic forms. Spectral decomposition of a matrix involving latent roots and vectors.

**Unit IV: Measure-I                                      1 credit (13 lectures)**

Limits of sequences of sets, fields and sigma-fields, Borel sets in  $\mathbb{R}^1$ , Measures and their elementary properties, continuity of finite measures, outer measures, extension theorem(discussion without proof), completion, Lebesgue sets and measures.

Recommended Books :

1. S. Lang Linear Algebra,
2. B.M. Singh(2007), An Introduction to Linear Algebra, ( South Asian Publishers),
3. S.R. Searle, Matrix Algebra Useful for Statistics, John Wiley

**STC416P: Practical based on STC416T**

**2 credits**

**Learning Outcomes:**

Students will be able to find

- (1) a basis of a vector space and its corresponding orthonormal vector
- (2) orthonormal projection of vector to another vector of same component,
- (3) orthonormal projection of vector to a vector space of same component,
- (4) characteristic roots and characteristic vectors of matrix,
- (5) spectral decomposition of matrix,
- (6) Characteristic polynomials and solution of system of linear equations.

**List of practicals:**

- 1) a basis of a vector space and its corresponding orthonormal vector
- 2) orthonormal projection of vector to another vector
- 3) orthonormal projection of vector to a vector space
- 4) independent solutions of a system of linear homogenous equations
- 5) independent solutions of a system of linear non-homogenous equations
- 6) diagonalization of square matrices
- 7) verification of  $\text{rank}(A+B) \leq \text{rank}(A) + \text{rank}(B)$
- 8) verification of Sylvester theorem
- 9) equivalent matrices
- 10) Square matrices

**Books recommended: Same to recommended books of ST-C416T.**

**STC417T: Measure Theory II & Statistical Inference IV**

**4 credits**

**Learning Outcomes:**

Students will acquire knowledge on

- Limits of Sequences of sets,
- Fields and sigma fields,
- Measures and properties, measurable functions and

- Integrability of measurable functions.
- Methods of Point estimation, Large sample properties, sequential analysis with Wald's SPRT.
- Non-parametric Inference, mean and median tests with goodness of fit problems.
- Hypothesis testing, N-P Lemma, UMP tests, unbiased and similar tests.

### **Unit I: Measure Theory II                      1 credit (13 lectures)**

Measurable functions, measurability theorem, measurability of indicators, measurable functions as the limit of sequences of simple functions; integrability, definite and indefinite integrals of simple functions, non-negative measurable functions and general measurable functions, monotone convergence and dominated convergence theorems.,

### **Unit II: Measure Theory III                      1 credit (13 lectures)**

Integration, integrability, definite and indefinite integrals of simple functions, non-negative measurable functions and general measurable functions, monotone convergence and dominated convergence theorems.,

### **Unit III: Non-parametric                                      1 credit (13 lectures)**

Non-parametric tests, single sample location, location cum symmetry, randomness and goodness of fit problems; U – statistic and properties, Kolmogorov test and its consistency, location problem- sign test, and its optimality, Wilcoxon sign rank test & its consistency, two sample problem- Kolmogorov –Smirnov test, run test, Wilcoxon-Mann-Whitney test, median test, consistency and asymptotic normality.

### **Unit IV: Statistical Inference IV                                      1 credit (13 lectures)**

Randomized tests and critical functions, N-P lemma for best test, Bayes and minimax tests, MLR families of distributions, UMP tests, unbiased tests, UMP unbiased tests, similar tests, locally best tests, tests with Neyman structure, UMP tests for K-parameter exponential family.

### **Books recommended:**

1. C.R Rao(1987), Linear Statistical Inference and its Applications, Wiley Eastern
2. Wald, Sequential Analysis, John Wiley
3. E.L. Lehman, Theory of Point Estimation, John Wiley
4. J.G. Gibbons, Non-parametric Statistical Inference, Marcel Dekker
5. B.M. Singh(2003), Measure, Probability and Stochastic Processes, South Asian, Publishers, New Delhi.

### **STC417P: Practical based on STC417T**

**2 credits**

### **Learning Outcomes:**

**Same to that of STC417T**

### **List of practicals:**

1. Kolmogorov – Smirnov test for goodness of fit.
2. Ordinary Sign rank test for single sample.
3. Wilcoxon Sign rank test for single sample.
4. Kolmogorov- Smirnov test for two Sample.
5. Run test for independence of two Samples.

6. Wilcoxon Signed test for two Samples
7. Median test.
8. Most Powerful test for Simple Vs Simple hypotheses of Parameters of Normal distribution.
9. Most Powerful test for Simple Vs Simple hypotheses Parameters of Binomial Distribution.
10. Most Powerful test for Simple Vs Simple hypotheses Parameters of Poisson distribution.
11. UMP unbiased test for mean of normal distribution.
12. UMP unbiased test for variance of normal distribution.
13. Most powerful test for one tail test (normal, binomial and normal).
14. Two sided test for the parameters of normal, binomial and Poisson distributions.
15. Some practical for regression and sample survey

**Recommended Books:** Same to Recommended Books of STC417T

#### **STC418T: Linear models, Sum of Squares, Regression III & Sample Survey IV 4 credit**

##### **Learning Outcomes:**

Students will acquire knowledge on

- Gauss-Markov linear model, estimable functions, BLUE, estimation and error spaces.
- Estimable parametric functions, sums of squares due to estimable linear function(s), linear hypotheses, generalized t and F tests.
- Simple and multiple linear regressions, polynomial fitting, outliers, homogeneity, heteroscedasticity, autocorrelation and multicollinearity,
- Ratio and Regression estimators, Cluster sampling, Two stage sampling, biases and errors

##### **Unit I: Linear models 1 credit (13 lectures)**

Linear models – fixed/random effects model, model of full rank/not of full rank with their consequences, estimable parametric functions and their BLUES, use of projections to get best estimates, normal equations, error function and Gauss-Markov theorem, estimation and error space.

##### **Unit II: Sum of Squares 1 credit (13 lectures)**

Sum of squares and degrees of freedom due to estimable parametric functions, Linear hypotheses, their tests and S.S. due to them, generalized t and F tests for estimable linear hypotheses and their particular cases with examples, testing a sub-hypotheses, comparison of means – Fisher, Tuckey, Scheffe and Duncan methods.

##### **Unit II: Regression III 1 credit (13 lectures)**

Simple linear regression, Multiple regression, methods of fitting, fit of polynomials and use of orthogonal polynomials. Test of fitness of regression models, residuals and their plots as test of departure from normality assumption, detection of outliers, test for homogeneity of variance, departure from Gauss-Markov setup, heteroscedasticity, autocorrelation and multicollinearity.

### **Unit III: Sample Survey IV                      1 credit (13 lectures)**

Ratio estimator(in SRS): estimation of the population mean and population total, bias of ratio estimators, approximate variance of ratio estimator, advantages and applications of ratio estimators, product estimator (concept only), Regression estimators (in SRS): bias of regression estimator, sampling variance of regression estimator, Non-sampling errors: Source and type, Non-sampling bias, non-response errors.

#### **Recommended Books:**

1. D.D. Joshi(2000), Linear Estimation and Design of Experiments, Wiley Eastern
2. A.M. Kshirsagar, A course in Linear Model, Marcel Dekker
3. Drapper and Smith, Applied Regression Analysis, John Wiley & Sons.
4. Hedayat, A. S. and Sinha, B.K. (1991): Design and inference in finite population sampling. Wiley.
5. P.V.Sukhatme, B.V.Sukhatme, S.Sukhatme and C.Asok(1984), Sampling theory of Survey with application, Indian Society of Agricultural Statistics, New Delhi

### **STC418P: Practical based on STC418T**

**2 credits**

#### **Learning Outcomes:**

**Same to that of STC418T**

#### **List of practicals:**

1. Fitting of orthogonal polynomial
2. Testing of departure from normality assumption.
3. Detection of outliers.
4. Testing for homogeneity of variance.
5. Testing of departure from Gauss-Markov setup, heteroscedasticity, autocorrelation and multicollinearity.
6. Estimation of ratio
7. Bias of ratio estimators (in SRS).
8. Approximate variance of ratio estimator.
9. Regression estimators (in SRS).
10. Bias of regression estimator.
11. Sampling variance of regression estimator.

**Recommended Books:** Same to Recommended Books of STC418T

### **Syllabi of Discipline Specific Electives (DSE)**

#### **STD301T: Time Series Analysis**

**4 Credits**

#### **Learning Outcomes:**

This course is meant to acquaint the students with some important but useful concepts on topics in time series analysis so that the students can get an important background material for taking up an advanced course in financial econometrics and data analysis. After completion of this course, the students will know about

- (a) Time series data, its applications to various fields and components of time series,
- (b) Fitting and plotting of various growth curves such as modified exponential, Gompertz and logistic curve,
- (c) fitting of trend by Moving Average method,

- (d) measurement of Seasonal Indices by Ratio-to-Trend, Ratio-to-Moving Average and Link Relative methods,
- (e) calculation of variance of random component by variate component method,
- (f) forecasting by exponential smoothing and shortterm forecasting methods such as Box Jenkins Method and Bayesian forecasting,
- (g) weak stationarity, autocorrelation and correlogram,
- (h) applications to real data by means of laboratory assignments.

**Contents:**

**Unit I 1 Credits (13 classes)**

Introduction to times series data, application of time series from various fields, Components of a times series, Decomposition of time series. Trend: Estimation of trend by free hand curve method, method of semi averages, fitting a various mathematical curve, and growth curves.

**Unit II 1 Credits (13 classes)**

Trend Cont.: Method of moving averages. Detrending. Effect of elimination of trend on other components of the time series. Seasonal Component: Estimation of seasonal component by Method of simple averages, Ratio to Trend.

**Unit III 1 Credits (13 classes)**

Seasonal Component count: Ratio to Moving Averages and Link Relative method, Deseasonalization. Cyclic Component: Harmonic Analysis. Some Special Processes: Moving-average (MA) process and Autoregressive (AR) process of orders one and two, Estimation of the parameters of AR (1) and AR (2) – Yule-Walker equations.

**Unit IV 1 Credits (13 classes)**

Random Component: Variate component method. Forecasting: Exponential smoothing methods, Short term forecasting methods: Brown's discounted regression, Box-Jenkins method and Bayesian forecasting. Stationary Time series: Weak stationarity, autocorrelation function and correlogram of moving average.

**STD301P: Practical based on STD301T**

**2 credits**

**List of practicals:**

1. Fitting and plotting of modified exponential curve.
2. Fitting and plotting of Gompertz curve.
3. Fitting and plotting of logistic curve.
4. Fitting of trend by Moving Average method.
5. Measurement of Seasonal Indices Ratio-to-Trend method.
6. Measurement of Seasonal Indices Ratio-to-Moving Average method.
7. Measurement of seasonal indices Link Relative method.
8. Calculation of variance of random component by variate difference method.
9. Forecasting by exponential smoothing.
10. Forecasting by short term forecasting methods.



**Recommended Books:**

1. Box, G.E.P., Jenkins, G.M., Reinsel, G.C. and Ljung, G.M. (2015). Time Series Analysis: Forecasting and Control. 5<sup>th</sup> Edition. John Wiley & sons, Inc.
2. Brockwell, P.J. and Davis, R.A. (2003). Introduction to Time Series Analysis. Springer.
3. Chatfield, C. (2001). Time Series Forecasting., Chapman & Hall.
4. Fuller, W.A. (1996). Introduction to Time Series. 2<sup>nd</sup> Edition. Wiley.
5. Kendall, M.G. and Ord, J.K. (1990). Time Series. 3<sup>rd</sup> Edition. Edward Arnold.
6. Montgomery, D.C., Jennings, C.L. and Kulahci, M. (2012). Introduction to Time Series Analysis and Forecasting, John Wiley.
7. Mukhopadhyay, P. (2011). Applied Statistics, 2<sup>nd</sup> Edition. Revised reprint, Books and Allied Pvt. Ltd.

**STD302T: Applied Statistics****4 Credits****Learning Outcomes:**

After going through this course, the students will have an idea of

- (a) income distributions and their fitting in real life situations,
- (b) commonly used measures of demography pertaining to its three basic aspects, viz. the fertility, mortality and migration,
- (c) various data collection methods enabling them to have a better insight in policy making, planning and systematic implementation,
- (d) Construction and implication of lifetables,
- (e) Population growth curves, population estimates and projections,
- (f) Real data implementation of various demographic concepts as outlined above through practical assignments.

**Contents****Unit I****1 Credits (13 classes)**

Analysis of income and allied size distributions: Pareto and log-normal distributions, genesis, specification and estimation, Lorenz curve, Gini coefficient.

Demand analysis: Classification of commodities, Engel curve analysis using cross-section and time series data, Engel curves incorporating household characteristics, demand projection, specific concentration curves.

**Unit II****1 Credits (13 classes)**

Sources of demographic data, census, registration, ad hoc surveys, hospital records, demographic profiles of the Indian census.

Measurement of Mortality and Life Table: Crude death rate, Standardized death rates, Age-specific death rates, Infant Mortality rate, Death rate by cause, Complete life table and its main features, Uses of life table.

**Unit III****1 Credits (13 classes)**

Measurement of Fertility: Crude birth rate, general fertility rate, age specific birth rate, total fertility rate, gross reproduction rate, net reproduction rate. Rates and ratios. Measures of mortality. Life Table – construction and applications.

**Unit IV****1 Credits (13 classes)**

Stable and stationary population. Measures of fertility and reproduction. Indian data.

Standardization of vital rates. Population growth curves, population estimates and projections.

Measures of migration. Use of demographic data for policy formulation.

**STD302P: Practical based on STD302T: 2 credits****List of practicals:**

1. Fitting of Engel's curve and calculation of income elasticity of demand.
2. Fitting of Pareto's law for income distribution for a given Income data set, for entire range as well as specific range.
3. Fitting of a Lorenz curve for a data and computation of the concentration ratio using graphical method.
4. Calculation of Crude birth rate; General fertility rate; Age specific fertility rate; Total fertility rate; Gross reproduction rate; Net reproduction rate.
5. Calculation of Infant mortality rate, Crude death rate, Age specific death rates.
6. Computation of standardized birth and death rates.
7. Construction of life tables.
8. Population growth curves, population estimates and projections.

**Recommended Books :**

1. Benjamin, B. (1959). Health and Vital Statistics. Allen and Unwin.
2. Cramer, J.S. (1969). Empirical Econometrics. North Holland Pub. Co.
3. Karmel, P.H. and Polasek, M. (1957). Statistics for Economists. Pitman Publishing.
4. Klein, L.R. (1962). An Introduction to Econometrics. Prentice Hall.
5. Mishra, B.D. (2004). An Introduction to the Study of Population. South Asian Publishers.
6. Mukhopadhyay, P. (1994). Applied Statistics. New Central Book Agency Pvt. Ltd. Calcutta.
7. Ramkumar, R. (1986). Technical Demography. John Wiley & Sons.
8. Srinivasan, K. (1998). Demographic Techniques and Applications. Sage Publications.
9. Srivastava O.S. (1983). A Text Book of Demography. Vikas Publishing House.
10. Shryock, H.S. (1971). The Methods and Materials in Demography. U.S. Bureau of Census.

**STD403T: Survival Analysis****4 Credits****Learning Outcomes:**

The course gives the application of statistics in handling survival data. The students will know about concepts of

- (a) Type-I (time), Type-II (order) and random censoring,
- (b) Survival Function, Failure rate, mean residual life, Total time on Test,
- (c) Applications of exponential, gamma, Weibull distributions, lognormal, Pareto, linear failure rate distributions to lifetime data,
- (d) Ageing properties of IFR, IFRA, DMRL, NBU, NBUE and HNBUE and Dual classes.
- (e) Actuarial and Kaplan –Meier estimator of survival function,
- (f) Cox’s proportional hazards and competing risk models,
- (g) tests for exponentiality,
- (h) Real lifetime data implementation of various concepts as outlined above through practical assignments.

## **Contents**

### **Unit I**

#### **1 Credits (13 classes)**

Concepts of Type-I (time), Type-II (order) and random censoring, Survival Function, Failure rate, mean residual life and their elementary properties. Total time on Test, bathtub failure rate. Life distributions: exponential, gamma, Weibull, lognormal, Pareto, linear failure rate.

### **Unit II**

#### **1 Credits (13 classes)**

Ageing classes (IFR, IFRA, DMRL, NBU, NBUE and HNBUE) and their properties, Dual classes, Interrelations between different ageing classes.

### **Unit III**

#### **1 Credits (13 classes)**

Estimation of survival function – Actuarial estimator, Kaplan –Meier estimator, Cox’s proportional hazards model, competing risks model.

### **Unit IV**

#### **1 Credits (13 classes)**

Definition of U statistics, tests for exponentiality versus positive ageing class such as IFR, IFRA, NBU.

### **STD403P: Practical based on STD303T**

#### **2 credits**

#### **List of practicals:**

1. Examples of Type-I (time), Type-II (order) and random censoring.
2. Finding Survival Function, Failure rate, mean residual life, Total time on Test.
3. Applications of exponential, gamma, Weibull distributions.
4. Applications of lognormal, Pareto, linear failure rate distributions.
5. Problems on ageing properties, IFR, IFRA, DMRL, NBU, NBUE and HNBUE and Dual classes.
6. Examples for Actuarial estimator and Kaplan–Meier estimator of survival function.
7. Applications of Cox’s proportional hazards model.
8. Applications of competing risks model.
9. Tests for exponentiality.

#### **Recommended Books :**

1. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data. Taylor and Francis.
2. Crowder, M. J. (2001). Classical Competing Risks. Chapman & Hall/CRC Press, London.
3. Deshpande, J. V. and Purohit, S.G. (2015). Lifetime Data: Statistical Models and Methods. 2<sup>nd</sup> Edition. World Scientific.

4. Gross, A.J. & Clark, V.A. (1976). Survival Distributions-Reliability Applications in Bio- medical Sciences. John Wiley and Sons.
5. Hanagal, D.D. (2011). Modeling Survival Data Using Frailty Models. Chapman & Hall. New York.
6. Kalbfleisch, J.D. and Prentice, R.L. (1980). The Statistical Analysis of Failure Time Data. John Wiley and Sons.
7. Miller, R.G. (1998). Survival Analysis. Second Edition. Wiley Interscience.

**STD404P: Project (based on sample survey/Design of experiments/Demography/Survival analysis/ etc.) 6 credits**

**Learning Outcomes:** , the students will have an idea of real life situations, will be able to analyse data and interpret it.

Students should submit a research report based on empirical study on some real life situation. The student will personally collect, analyze, interpret the data and prepare a report under the supervision of a faculty.

**References:**

1. Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers.
2. Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE Publications.

**Generic Electives/Interdisciplinary Papers (6 credits each) (Statistics students will opt 6 GE papers offered by other Departments/Disciplines. Students from other Departments/disciplines shall opt. 6 papers from the following 6 GE courses.)**

**STG201T: Introduction to Statistics-I 4 credits (15 Classes)**

**Learning Outcomes:**

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will make the students conversant with

- (a) Various techniques used in summarization, presentation and analysis of different types of Statistical data,
- (b) Various summary measures of central tendency, dispersion, moments, skewness and kurtosis.
- (c) Simple and rank correlation, Partial and Multiple correlation coefficients.
- (d) Fitting of linear and quadratic regressions using principle of least squares.
- (e) Measures of association for 2x2 and rxs contingency tables.
- (f) have knowledge on theoretical as well as practical approach.

**Contents:****Unit I 1 Credits (13 classes)**

Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Scales of measurement -nominal, ordinal, interval and ratio. Variables and attributes, Diagrammatical Representation of Data, Summarization of Data: Frequency Distribution and Graphical Presentation.

**Unit II 1 Credits (13 classes)**

- Notion of Central Tendency : Average, characteristics of an ideal average.
- Arithmetic Mean (A.M): Definition, effect of change of origin and scale, combined mean of a number of groups, merits and demerits, its applications.
- Mode: Definition, formula for computation (with derivation), graphical method of Determination of mode, merits and demerits, its applications.
- Median : Definition, formula for computation (with derivation), graphical method of Determination of median, merits and demerits, its applications.
- Empirical relation between mean, median and mode.

**Unit III 1 Credits (13 classes)**

- Partition Values : Quartiles, Deciles and Percentiles, their applications.
- Geometric Mean (G.M) : Definition, merits and demerits, its applications
- Harmonic Mean (H.M) : Definition, merits and demerits, its applications
- Relation between A.M., G.M., and H.M.
- Weighted Mean : Weighted A.M., G.M., and H.M.
- Box-plot

**Unit IV 1 Credits (13 classes)**

- Concept of dispersion, characteristics of an ideal measure of dispersion.
- Range : Definition, merits and demerits.
- Semi-interquartile range (Quartile deviation).
- Mean deviation : Definition, merits and demerits,
- Mean square deviation : Definition, Variance and standard deviation – definition, merits and demerits, effect of change of origin and scale.
- Determination of variance of a combined series.
- Measures of dispersion for comparison : coefficient of range, coefficient of quartile Deviation and coefficient of mean deviation, coefficient of variation (C.V.)

**STG201P: Practical based on STG201P 2credits****Contents:**

1. Identification of scales of measurement and variables.
2. Diagrammatical representation of data, Summarization of data: Frequency Distribution and graphical Presentation.
3. Measures of central tendency: mathematical and positional.  
Calculation of mean, median, mode, range, semi-interquartile range mean deviation, mean square deviation, Variance, standard deviation, coefficient of range, coefficient of quartile
4. Deviation and coefficient of mean deviation, coefficient of variation (C.V.)

**Recommended Books:**

1. Gun, A.M., Gupta, M.K. and Das gupta, B. (2013). Fundamental of Statistics, Vol I, World Press, Kolkata.
2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.

3. Hanagal, D.D.(2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
4. Miller, I. and Miller, M.(2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
5. Mood, A.M. Graybill, F.A. and Boes, D.C.(2011). Introduction to the Theory of Statistics, 3<sup>rd</sup> Edn., (Indian Edition), Tata Mc Graw-Hill Pub. Co. Ltd.

### **STG202T: Introduction to Statistics-II**

**4 credits**

#### **Learning Outcomes:**

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will make the students conversant with

- (a) Various summary measures of dispersion, moments, skewness and kurtosis.
- (b) Simple and rank correlation, Partial and Multiple correlation coefficients.
- (c) Measures of association for 2x2 and rxs contingency tables.
- (d) have knowledge on attributes and Chi-square.

#### **Contents:**

##### **Unit I**

**1 Credits (13 classes)**

- Raw moments for grouped and ungrouped data.
- Moments about arbitrary constant for grouped and ungrouped data.
- Central moments for grouped and ungrouped data, Effect of change of origin and Scale, Sheppard's correction for moments upto fourth order (without proof).
- Relations between central moments and raw moments (upto fourth order).
- Karl Pearson's  $\beta$  and  $\gamma$  coefficients

##### **Unit II**

**1 Credits (13 classes)**

###### **Moments**

- Raw moments for grouped and ungrouped data.
- Moments about arbitrary constant for grouped and ungrouped data.
- Central moments for grouped and ungrouped data, Effect of change of origin and Scale, Sheppard's correction for moments upto fourth order (without proof).
- Relations between central moments and raw moments (upto fourth order).
- Karl Pearson's  $\beta$  and  $\gamma$  coefficients

##### **Unit III**

**1 Credits (13 classes)**

###### **Skewness and Kurtosis**

- Concept of skewness of frequency distribution, positive, negative skewness, symmetric frequency distribution.
- Bowley's coefficient of skewness.
- Karl Pearson's coefficient of skewness
- Measures of skewness based on moments
- Concepts of kurtosis, leptokurtic and platykurtic frequency distributions.
- Measures of kurtosis based on moments

##### **Unit IV**

**1 Credits (13 classes)**

Bivariate data: Definition, scatter diagram, simple correlation, rank correlation.

Trivariate Data: Partial and Multiple correlation coefficients. Attributes and Chi-square.

**STG202P: Practicals based on STG202T****2 credits****List of practicals:**

1. Identification of scales of measurement, variables and attributes.
2. Moments, measures of skewness and kurtosis.
3. Scatter diagram, simple correlation, rank correlation.
4. Partial and Multiple correlation coefficients.
5. Fitting of linear and quadratic regression using principle of least squares.
6. Measures of association for 2x2 and rxs contingency tables
7. Calculation of Chi-square

**Recommended Books:**

1. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I World Press, Kolkata.
2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II, World Press, Kolkata.
3. Hanagal, D. D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.

**STG303T: Introduction to Probability Theory****4 credits (15 Classes)**

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS). This course will lay the foundation to probability theory and Statistical modeling of outcomes of real life random experiments through various Statistical distributions.

**Learning Outcomes:**

The students will get to know about

- (a) Writing of sample space, events and algebra of events and finding Probability of events,
- (b) Conditional Probability and applications of Theorem of total probability and Bayes' theorem,
- (c) Discrete and continuous Random Variables, Probability mass function (p.m.f.) and Probability density function (p.d.f.), Cumulative distribution function (c.d.f.)
- (d) Expectation, variance, moments and moment generating function.
- (e) Problem solving pertaining to binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma distributions.
- (f) fitting of Binomial, Poisson and Normal distributions
- (g) Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.),
- (h) Various aspects as outlined above through practical assignments.

**Contents:****Unit I 1 Credits (13 classes)**

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability—classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications.

**Unit II 1 Credits (13 classes)**

Random Variables: Discrete and continuous random variables, Probability mass function (p.m.f.), Probability density function (p.d.f.), Cumulative distribution function (c.d.f.) Illustrations of random variables and their properties. Expectation, variance, moments and moment generating function.

**Unit III 1 Credits (13 classes)**

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma and their applications. Fitting of Binomial, Poisson and Normal Distributions

**Unit IV 1 Credits (13 classes)**

Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in Distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.).

**STG303P: Practicals based on STG303T 2 credits****List of Practicals:**

1. Writing sample space, events and algebra of events.
2. Finding Probability of events.
3. Computing Conditional Probability, Use of laws of addition and multiplication, Problems on independent events, theorem of total probability and applications of Bayes' theorem.
4. Identifying Discrete and continuous Random Variables, writing Probability mass function (p.m.f.) and Probability density function (p.d.f.), Finding Cumulative distribution function (c.d.f.)
5. Finding Expectation, variance, moments and moment generating function.
6. Problem solving pertaining to binomial, Poisson, geometric, negative binomial, hyper geometric, uniform, normal, exponential, beta, gamma distributions.
7. Fitting of Binomial, Poisson and Normal distributions
8. Problems on Chebyshev's inequality, Convergence in probability, Weak law of large numbers, Convergence in distribution, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorems (C.L.T.).

**Recommended Books:**

1. Hanagal, D.D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
2. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009). Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
3. Meyer, P.L. (1970). Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.



4. Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
5. Rohatgi, V.K. and Saleh A.K.M.E. (2008). An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.

#### **STG304T: Introduction to Statistical Inference     4 Credits**

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS).

##### **Learning Outcomes:**

The students will get an exposure to

- (a) Techniques of estimation and testing of hypotheses for mean, variance, proportions, correlation coefficient, association and goodness of fit,
- (b) Confidence intervals for the parameters of a normal distribution (one and two-sample problems),
- (c) Test of significance for correlation coefficient, Fisher's  $z$ -transformation,
- (d) Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction,
- (e) analysis of variance technique for one and two way classifications,
- (f) analysis of commonly used experimental designs such as CRD, RCBD etc.,
- (g) non-parametric tests such as Sign test for median and symmetry, Wilcoxon two-sample test,
- (h) practical applications through laboratory assignments.

##### **Contents:**

###### **Unit I**

###### **1 Credits (13 classes)**

Estimation of population means, confidence intervals for the parameters of a normal distribution (one and two-sample problems).

The basic idea of significance test, Null and alternative hypothesis. Type I & Type II errors, level of significance, concept of  $p$ -value. Tests of hypotheses for the parameters of a normal distribution (one and two-sample problems).

###### **Unit II**

###### **1 Credits (13 classes)**

Test of significance for correlation coefficient. Fisher's  $z$ -transformation,

Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction.

###### **Unit III**

###### **1 Credits (13 classes)**

Analysis of variance, one-way and two-way classifications. Brief exposure of three basic principles of design of experiments, treatment, plot and block. Analysis of completely randomized design, randomized complete block design.

###### **Unit IV**

###### **1 Credits (13 classes)**

Basic idea of non-parametric tests, sign test for median, sign test for symmetry, Wilcoxon two-sample test.

**STG304P: Practicals based on STG304T****List of practicals:**

1. Estimation of population means,
2. Finding confidence intervals for the parameter of a normal distribution (one and two-sample problems).
3. Tests of hypotheses for the parameters of a normal distribution (one and two-sample problems).
4. Test of significance for correlation, coefficient, Fisher's z-transformation.
5. Tests of proportions, tests of association and goodness-of-fit using Chi-square test, Yates' correction.
6. Analysis of variance (one-way and two-way classifications).
7. Sign test for median and sign test for symmetry.
8. Wilcoxon two-sample test.

**Recommended Books :**

1. Chap, T.L. and Eberly, L.E. (2016). Introductory Biostatistics. Wiley.
2. Daniel Wayne W. and Cross, C.L. (2013). Bio-statistics: A foundation for Analysis in the Health Sciences. John Wiley.
3. Das, M.N. and Giri, N.C. (1986). Design and analysis of experiment, Second Edition. John Wiley.
4. Dunn, O.J. and Clarke V.A. (2009). Basic Statistics: A Primer for the Biomedical Sciences, Fourth Edition. John Wiley.
5. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2013). Fundamental of Statistics, Vol I. World Press, Kolkata.
6. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol II. World Press, Kolkata.
7. Hanagal, D.D. (2009). Introduction to Applied Statistics: A Non-Calculus Based Approach. Narosa Publishing Comp. New Delhi.
8. Pagano, M. and Gauvreau, K. (2018). Principles of Biostatistics, Second Edition. Chapman and Hall/CRC.

**STG405T: Introduction to Applied Statistics****4 credits (15 classes)****Learning Outcomes:**

This course is designed for students other than statistics discipline and can be opted as choice based credit system (CBCS).

The course will expose the students to

- (a) time series, index numbers, quality control and demographic methods,
- (b) different methods of measurements in time series
- (c) computation of different types of index numbers, consumer price index number,
- (d) quality control charts for variables and attributes helpful in industry for maintaining quality,
- (e) measures of fertility and mortality useful for helping the govt. to make decisions,
- (f) practical applications of the various concepts outlined above.

**Contents:****Unit I****1 Credits (13 classes)**

Economic Time Series: Component of time series, Decomposition of time series-Additive and multiplicative models with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve. Method of semi-average and method of least squares (linear, quadratic and modified exponential). Measurement of seasonal variations by method of ratio to trend.

**Unit II****1 Credits (13 classes)**

Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index number of prices and quantities, consumer price index number. Uses and limitation of index numbers.

**Unit III****1 Credits (13 classes)**

Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable causes. General theory of control charts, process & product control, control charts for variables:  $\bar{x}$  and R-charts. Control charts for attributes: p and c charts

**Unit IV****1 Credits (13 classes)**

Demographic Methods: Introduction to measurement of population, rates and ratios of vital events. Measurement of mortality: Crude Death Rate (CDR), Standardised Death Rate (SDR) (w.r.t. age and sex). Measurement of fertility and reproduction: Crude Birth Rate (CBR), Gross Fertility Rate (GFR) and Total fertility rate (TFR). Life (mortality) tables: definition of its main functions and uses, Measurement of population growth: Gross Reproduction Rate (GRR), Net Reproduction Rate (NRR).

**STG405P: Practicals based on STG405T****List of practicals:**

1. Measurement of trend by method of free-hand curve. Method of semi-average and method of least squares (linear, quadratic and modified exponential). Measurement of seasonal variations by method of ratio to trend.
2. Computation of different type so find exnumbers, consumer price index number.
3. X and R charts
4. p and c charts
5. Computation of Crude Death Rate (CDR), Standardised Death Rate (SDR) (w.r.t. Age and sex).
6. Computation of Crude Birth Rate (CBR), Gross Fertility Rate (GFR) and Total fertility rate (TFR).
7. Completion of a life table by computing values of different functions.
8. Computation of Gross Reproduction Rate (GRR), Net Reproduction Rate (NRR).

**Recommended Books:**

1. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2011). Fundamental of Statistics, Vol III. World Press, Kolkata.
2. Gupta, S.C. and Kapoor, V.K. (2008). Fundamentals of Applied Statistics. 4<sup>th</sup> Edition (Reprint), Sultan Chand & Sons.
3. Montgomery, D.C. (2009). Introduction to Statistical Quality Control. 6<sup>th</sup> Edition, Wiley India Pvt. Ltd.
4. Mukhopadhyaya, P. (1999). Applied Statistics. New Central Book Agency, Calcutta.

**STG406T: Introduction to Operations Research****4 credits (13 classes)****Learning Outcomes:**

The students shall get exposed to

- (a) Graphical and simplex method of solving linear programming problem(LPP) for finding degenerate, unbounded, alternate and infeasible solutions,
- (b) use of duality to solve aLPP,
- (c) obtaining solution of a transportation problem by North West corner method, Matrix Minima method, Vogel's method,
- (d) Hungarian Method for solving assignment problems,
- (e) game theory, minimax-maximin rules, graphical solution of  $m \times n$  or  $2 \times n$  rectangular game and mixed strategy,
- (f) network problem using shortest route.

**Contents:****Unit I**

Introduction to Operations Research (OR), phases of OR, model building, various types of OR problems. Linear Programming Problem, Mathematical formulation of the LPP, graphical solutions of aLPP.

**Unit II****1 Credits (13 classes)**

Optimum solution to a LPP: Simplex method, concept of artificial variables and Charne's big M-technique. Graphically identifying special cases of LPP. Concept of duality in LPP.

**Unit III****1 Credits (13 classes)**

Transportation Problem: Initial solution by north west corner rule, least cost method and Vogel's approximation method (VAM), MODI's method to find the optimal solution. Assignment problem: Hungarian method to find optimal assignment.

**Unit IV****1 Credits (13 classes)**

Game theory: Rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. Networking: Shortest route problem

**STG406T: Practicals based on STG406T****List of practicals:**

1. Mathematical formulation of LPP and solving the problem using graphical method.
2. Simplex technique to solve LPP and reading dual solution from the optimal table.
3. Charne's Big M-method involving artificial variables.
4. Identifying special cases: Degenerate solution, unbounded solution, Alternate solution and infeasible solution by Graphical method and interpretation.
5. Allocation problem using Transportation model.
6. Allocation problem using Assignment model.
7. Networking: Shortest route problem.
8. Problem based on game matrix:  $m \times n$  Rectangular and Mixed strategies.

**Recommended Books:**

1. Ravindran, A. Phillips, D.T. and Solberg, J.J. (2005). Operations Research- Principles and Practice. John Wiley & Sons.
2. Swarup, K. Gupta, P.K. and Mohan, M. (2007). Operations Research, 13<sup>th</sup> Edition. Sultan Chand and Sons.
3. Taha, H.A. (2007). Operations Research: An Introduction, 8<sup>th</sup> Edition. Prentice Hall of India.

**Skill Enhancement Courses (4 credits each) (Any 2 papers to be selected)****STS101T: Computational Techniques and R Programming 3 credits****Learning Outcomes:**

The students will get acquainted with

- (a) Various basic concepts related to computer architecture and its organization, various peripheral devices,
- (b) languages: machine language, assembly language and high level languages,
- (c) ideas on operating systems, linker, loader and compiler etc.,
- (d) R programming with some basic notions for developing their own simple programs and visualizing graphics in R.

**Contents:****Unit I (12 classes)**

Computer basics: Introduction and brief history of evolution of computers, Classification of computers: special purpose and general purpose; analog, digital and hybrid; Super, main-frame etc.

**Unit II (12 classes)**

Organization of general purpose digital computers: CPU, main memory and peripherals. Mass storage devices and other I/O devices.

Computer languages: Machine code language (machine language), assembly language and high level languages. Software: Operating systems, linker, loader, compiler, interpreter and assembler.

**Unit III (12 classes)**

Computer programming: Algorithm and flow-chart. Storage of information: concepts of records and files. File organization: sequential, relative and indexed.

**Unit IV (12 classes)**

Programming with R: Introduction to R, Data types in R (numeric, logical, character, complex etc.), R objects: vector, matrix, array, list, data frame, factor, and time series. Arithmetic logical and relational operators, explicit and implicit looping, functions and functional programming in R, Lexical scoping rules in R, benefits of Lexical scoping, other scoping rules, debugging facility in R. Few important mathematical, statistical and graphical functions in R.

**STS101P: Practicals are based on the topics of the theory mentioned above.**

**1 Credit**

**Recommended books:**

1. Chambers, J. (2008). Software for Data Analysis: Programming with R, Springer.
2. Crawley, M.J. (2017). The R Book, John Wiley & Sons.
3. Eckhouse, R.H. and Morris, L.R. (1975). Minicomputer Systems Organization, Programming and Applications, Prentice-Hall.
4. Matloff, N. (2011). The Art of R Programming, No Starch Press, Inc.
5. Peter, N. (1986). Inside the IBM PC, Prentice-Hall Press.

**STS102T: Statistical Techniques for Research Methods 3 credits**

**Learning Outcomes:**

Statistical Techniques provide scientific approaches to develop the domain of human knowledge largely through empirical studies. The course will enable the students to

- (a) Understand basic concepts and aspects related to research, data collection, analyses and interpretation,
- (b) Prepare and finalize research report on some real life situations.

**Contents:**

**Unit I (12 classes)**

Introduction: Meaning, objectives and motivation in research, types of research, research approach, significance of research. Research problems: definition, selection and necessity of research problems.

**Unit II (12 classes)**

Survey methodology and data collection, inference and error in surveys, the target populations, sampling frames and coverage error, methods of data collection, non-response, questions and answers in surveys.

**Unit III (12 classes)**

Processing, Data Analysis and Interpretation: Review of various techniques for data analysis covered in core statistics papers, techniques of interpretation, precaution in interpretation.

**Unit IV (12 classes)**

Develop a questionnaire, collect survey data pertaining to a research problem (such as gender discriminations in private v/s government sector, unemployment rates, removal of subsidy, impact on service class v/s unorganized sectors), interpret the results and draw inferences.

**STS102P: Practical/Project based on STS102T**

Students should submit a research report based on empirical study on some real life situation. The student will personally collect, analyze, interpret the data and prepare a report under the supervision of a faculty.

**References:**

1. Kothari, C.R. (2009): Research Methodology: Methods and Techniques, 2nd Revised Edition reprint, New Age International Publishers.
2. Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE Publications.