Choice Based Credit System (CBCS)

UNIVERSITY OF DELHI

DEPARTMENT OF STATISTICS

Learning Outcomes-based Curriculum Framework (LOCF)

of

BACHELOR OF SCIENCE (HONS.) IN STATISTICS

(B.Sc. (Hons.) Statistics)

(Effective from Academic Year 2019-20)

PROPOSED SYLLABUS

XXXXX Revised Syllabus as approved by Academic Council on XXXX, 2019 and

Executive Council on YYYY, 2019

1. Introduction to Programme

B.Sc. (Hons.) Statistics is a three-year undergraduate program with specialization in statistics. The programme fosters interdisciplinary approach to the study of Statistics, Mathematics, and Computers aiming to promote holistic education useful in handling social, economics, engineering, physical and bio-sciences problems. The curriculum is dispensed using a combination of classroom teaching, project-based learning, practical's, group discussions, presentations, home assignments, industry interactions and exposure, internships and fieldwork. The programme has a unique and innovative course structure which engenders creative out of the box thinking.

1.1 Eligibility for Admissions

As per admission bulletin for under-graduate programme of University of Delhi.

2. Introduction to CBCS (Choice Based Credit System)

Scope:

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill-based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Grading system provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on students' performance in examinations enables the student to move across institutions of higher learning. The uniformity in evaluation system also enable the potential employers in assessing the performance of the candidates.

Definitions:

(i). 'Academic Programme' means an entire course of study comprising its programme structure, course details, evaluation schemes etc. designed to be taught and evaluated in a teaching Department/Centre or jointly under more than one such Department/Centre.

(ii). 'Course' means a segment of a subject that is part of an Academic Programme.

(iii). 'Programme Structure' means a list of courses (Core, Elective, Open Elective) that makes up an Academic Programme, specifying the syllabus, Credits, hours of teaching, evaluation and examination schemes, minimum number of credits required

for successful completion of the programme etc. prepared in conformity to University Rules, eligibility criteria for admission.

(iv). 'Core Course' means a course that a student admitted to a particular programme must successfully complete to receive the degree and which cannot be substituted by any other course.

(v). 'Elective Course' means an optional course to be selected by a student out of such courses offered in the same or any other Department/Centre.

(vi). 'Discipline Specific Elective' (DSE) course is the domain specific elective course offered by the main discipline/subject of study. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature also, but these are needed to be offered by main discipline/subject of study.

(vii). 'Dissertation/Project' is an elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member. Project work/Dissertation is considered as a special course involving application of knowledge in solving / analysing / exploring a real life situation / difficult problem. A Project/Dissertation work would be of 6 credits. A Project/Dissertation work may be given in lieu of a discipline specific elective paper.

(viii). 'Generic Elective' (GE) course is an elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure to other disciplines. A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.

(ix). 'Ability Enhancement Courses' (AEC) also referred as Competency Improvement Courses/Skill Development Courses/Foundation Course. The Ability Enhancement Courses (AEC) may be of two kinds: AE Compulsory Course (AECC) and AE Elective Course (AEEC).

(x). 'AECC' are the courses based upon the content that leads to Knowledge enhancement. The two AECC are: Environmental Science, English/ MIL Communication.

(xi). 'AEEC' are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc. These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based instruction. These courses are also referred to as Skill Enhancement Courses (SEC).

(xii). 'Credit' means the value assigned to a course which indicates the level of instruction; One-hour lecture per week equals 1 Credit, 2 hours practical class per week equals 1 credit. Credit for a practical could be proposed as part of a course or as a separate practical course

(xiii). 'CGPA' is cumulative grade points calculated for all courses completed by the students at any point of time.

(xiv). 'SGPA' means Semester Grade Point Average calculated for individual semester.

(xv). 'CGPA' is Cumulative Grade Points Average calculated for all courses completed by the students at any point of time. CGPA is calculated each year for both the semesters clubbed together.

(xvi). 'Grand CGPA' is calculated in the last year of the course by clubbing together of CGPA of two years, i.e., four semesters. Grand CGPA is being given in Transcript form. To benefit the student a formula for conversation of Grand CGPA into %age marks is given in the Transcript.

3. Programme Structure

The B.Sc. (Hons.) Statistics is a three year programme divided into six semesters. A student is required to complete 148 credits for the completion of programme and the award of degree.

3.1 Alignment with CBCS

The B.Sc. (Hons.) Statistics programme is aligned with CBCS structure as given in Table 1

Table 1: CBCS Course Structure for B.Sc. (Hons.) Programme

Course	***Credits**	
	Theory+ Practical	Theory + Tutorial
I. Core Course		
(14 Papers)	14X4= 56	14X5=70
Core Course Practical / Tutorial*		
(14 Papers)	14X2=28	14X1=14
II. Elective Course		
(8 Papers)		

A.1. Discipline Specific Elective	4X4=16	4X5=20
(4 Papers)		
A.2. Discipline Specific Elective Practical/ Tutorial*	4 X 2=8	4X1=4
(4 Papers)		
B.1. Generic Elective/ Interdisciplinary	4X4=16	4X5=20
(4 Papers)		
B.2. Generic Elective Practical/ Tutorial*	4 X 2=8	4X1=4
(4 Papers)		

- Optional Dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6th Semester

III. Ability Enhancement Courses

1. **Ability Enhancement Compulsory**		
(2 Papers of 4 credit each)	2 X 4=8	2 X 4=8
Environmental Science		
English/MIL Communication		
2. **Ability Enhancement Elective** (Skill Based) (Minimum 2)		
(2 Papers of 4 credit each)	2 X 4=8	2 X 4=8
Total credit	**148**	**148**

Institute should evolve a system/policy about Interest/Hobby/Sports/NCC/NSS/related courses on its own.

*** Wherever there is a practical there courses will be no tutorial and vice-versa**

3.2 Details of Programme

Core Papers (Credits: 6 each) (14 papers)

STAT-C-101 Descriptive Statistics (Theory+ Practical)
STAT C-102 Calculus (Theory+ Tutorial)
STAT-C-201 Probability and Probability Distributions (Theory+ Practical)
STAT C-202 Algebra (Theory+ Practical)
STAT-C-301 Sampling Distributions (Theory+ Practical)
STAT-C-302 Survey Sampling and Indian Official Statistics (Theory+ Practical)
STAT C-303 Mathematical Analysis (Theory+ Practical)
STAT-C-401 Statistical Inference (Theory+ Practical)
STAT-C-402 Linear Models (Theory+ Practical)
STAT-C-403 Statistical Quality Control (Theory+ Practical)
STAT-C-501 Stochastic Processes and Queuing Theory (Theory+ Practical)
STAT-C-502 Statistical Computing Using C/C++ Programming (Theory+ Practical)
STAT-C-601 Design of Experiments (Theory+ Practical)
STAT-C-602 Multivariate Analysis and Nonparametric Methods (Theory+ Practical)

Discipline Specific Elective Papers (Credits: 6 each) (4 papers to be selected)

DSE-1

(A) Time Series Analysis (Theory+ Practical) or
(B) Demography and Vital Statistics (Theory+ Practical)

DSE-2

(A) Operations Research (Theory+ Practical) or
(B) Econometrics (Theory+ Practical)

DSE-3

(A) Actuarial Statistics (Theory+ Practical) or
(B) Biostatistics and Survival Analysis (Theory+ Practical)

DSE-4

(A) Financial Statistics (Theory+ Practical) or
(B) Project Work (Sixth Semester)

Skill Enhancement Courses (Credits: 4 each) (2 papers to be selected)

1. Statistical-Data Analysis Using Software Packages
2. Statistical Data Analysis Using R
3. Statistical Techniques for Research Methods
4. Statistical Simulation Techniques

Generic Elective Papers (GE) (Credits: 6 each) (to be offered to other Departments/Disciplines)

1. Statistical Methods
2. Introductory Probability

3. Basics of Statistical Inference
4. Applied Statistics

Note:

1. There will be one batch of 15 students for practical classes.
2. Each practical will carry 50 marks including 25 marks for continuous evaluation and 5 marks for the oral test.
3. Colleges are advised and encouraged to conduct at least 50% of the practicals using spreadsheet (MS Excel) or any statistical package (SPSS/R/MATLAB).
4. At least four questions have to be compulsorily attempted in the final practical examination.
5. Hardcopy of practical file has to be maintained by the students for each practical paper.

3.3 Semester-wise Placement of Courses

Table 2: Semester wise Details of B.Sc. (Hons.) Statistics Course & Credit Scheme

Year	Semester	Core Course	Ability Enhancement Compulsory Course (AEC)	Skill Enhancement Course (SEC)	Discipline Specific Elective (DSE)	Generic Elective (GE)	Semester-wise Credits
I	I	STAT-C-101: Descriptive Statistics (L+P) STAT -C-102: Calculus (L+T)	AECC 1			STAT-GE-1 (L+P)	22
	L+T/P	4+2=6; 5+1=6.	4			4+2=6	
	II	STAT-C-201: Probability and Probability Distributions (L+P) STAT -C-202: Algebra (L+P)	AECC 2			STAT-GE-2 (L+P)	22
	L+T/P	4+2=6; 4+2=6.	4			4+2=6	
II	III	STAT-C-301:Sampling Distributions (L+ P) STAT-C-302: Survey Sampling and Indian Official Statistics (L+ P) STAT-C-303: Mathematical Analysis (L+ P)		SEC (1/2/3/4) (L+P)		STAT-GE-3 (L+P)	28
	L+T/P	4+2=6; 4+2=6; 4+2=6.		2+2=4		4+2=6	
	IV	STAT-C-401: Statistical Inference (L+ P) STAT-C-402: Linear Models (L+ P) STAT-C-403: Statistical Quality Control (L+ P)		SEC (1/2/3/4) (L+P) Different from semester III option (L+P)		STAT-GE-4 (L+P)	28
	L+T/P	4+2=6; 4+2=6; 4+2=6.		2+2=4		4+2=6	

III	V	STAT-C-501: Stochastic Processes and Queuing Theory (L+ P)			DSE-1-(A/B) (L+P)		24
		STAT-C-502: Statistical Computing Using C/C++ Programming (L+ P)			DSE-2-(A/B) (L+P)		
	L+T/P	4+2=6; 4+2=6.			4+2=6; 4+2=6.		
	VI	STAT-C-601: Design of Experiments (T+ P)			DSE-3-(A/B) (L+P)		24
		STAT-C-602: Multivariate Analysis and Nonparametric Methods (T+ P)			DSE-4-(A/B) (L+P)		
	L+T/P	4+2=6; 4+2=6.			4+2=6; 4+2=6.		
					Total Credits		**148**

Legend: L -Lecture Class; T =Tutorial Class; P = Practical Class
Note: One-hour lecture per week equals 1 Credit, 2 hours practical class per week equals 1 credit.

3.4 Number of Courses offered

Table 3: Number of courses offered

S. No.	Course Type	No. of Courses
1.	Core Course	14
2.	Ability Enhancement Compulsory Course (AEC)	4
3.	Skill Enhancement Course (SEC)	4
4.	Discipline Specific Elective (DSE)	8
5.	Generic Elective (GE)	4
	Total Number of Courses Offered	**34**

4. Learning Outcome Based Approach

B.Sc. (Hons.) Statistics programme is designed in such a way that students will be exposed to the real world data related to industries and society, identifying the problems and working towards their solutions through various analytical and statistical techniques. The course is designed to imbibe strong foundation of statistics in students.

5. Graduate Attributes

On completion of the programme students are expected to have acquired the skills of effective communication, critical thinking, social research methods and social outreach. The attributes expected from the graduates of B.Sc. (Hons.) Statistics are:

i. A holistic knowledge and understanding of basic concepts in statistics and its linkages with art, science and technology.
ii. The capacity to identify, understand and solve the problems of society.
iii. The ability to collect, analyse, interpret and present the data and bring out the meaning, correlations and interrelationships.
iv. Team building and leadership skills, communication, creative and critical thinking skills, and innovative problem solving skills.
v. To provide scientific approaches to develop the domain of human knowledge through the use of empirical data expressed in quantitative form.
vi. To enable the students to understand basic concepts and aspects related to research, various techniques to collect the data, analyse the data and interpret the results thereafter.
vii. Learning the basic programming languages and statistical software will help students to easily switch over to any other statistical software in future.

6. Qualification Description

Upon successfully completing the Programme the students will be conferred a degree of B.Sc. (Hons.) Statistics. It is an inter-disciplinary programme equipping the students in the knowledge of statistics. Besides, it also imparts the requisite knowledge of mathematics and statistical softwares.

7. Programme Objectives

1. To imbibe strong foundation of statistics in students.
2. To familiarize students with basic to high-level statistical concepts.
3. To update students with mathematical tools that aid in statistical theory.
4. To teach/strengthen students' knowledge of spreadsheets, programming languages and statistical packages.
5. To promote application-oriented pedagogy by exposing students to real world data.
6. To make students do projects, which prepares them for jobs/markets.

8. Programme Learning Outcomes

This course exposes the students to the beautiful world of Statistics and how it affects each and every aspect of our daily life. The course is designed to equip students with all the major concepts of Statistics along with the tools required to implement them. Introduction to computer softwares help them in analysis of data by making optimum usage of time and resources. These sofwares give them the necessary support and an edge when progressing to their professional careers. Exposure to plethora of real life data helps in honing their analytical skills. Having practical component with every paper invokes their exploratory side and fine-tunes the interpretation abilities. Such a pedagogy goes a long way in giving them the required impetus and confidence for consultancy startups/jobs in near future. The structure of the course also motivates/helps the students to pursue careers in related disciplines, especially the data sciences, financial statistics and actuarial sciences.

9. Teaching Learning Process

The faculty of the Statistics department in the constituent colleges of the University of Delhi is primarily responsible for organizing lectures for B.Sc. (Hons.) Statistics. The instructions related to tutorials and practicals are provided by the respective registering units under the overall guidance of the Department of Statistics, University of Delhi.

There shall be 90 instructional days excluding examination in a semester.
(Add details about Projects/Dissertation and role of supervisor)

Teaching Pedagogy:

Teaching pedagogy involves class room interactions, discussions, presentations, practical work based on courses, class tests and assignments.

This is detailed out for each course of the programme in section 11 under "**Facilitating the Achievement of Course Learning Outcomes**".

10. Assessment Methods/ Evaluation Scheme

The students registered for B.Sc. (Hons.) Statistics programme will study semester I to VI at the constituent colleges of the University Delhi. During these semesters Core, AECC, DSE and SEC courses are offered.

(i) English shall be the medium of instruction and examination.

(ii) Examinations shall be conducted at the end of each Semester as per the Academic

calendar notified by the University of Delhi.

(iii) The assessment broadly comprise of internal assessment and end semester examination. Each theory paper will be of 100 marks with 25% marks for internal assessment and 75% marks for end semester examination. Each practical paper will be examined out of 50 marks with 50% marks for continuous evaluation and 50% marks for end semester examination. Skill enhancement paper will be examined out of 100 marks.

10.1 Pass Percentage & Promotion Criteria:

The following provisions shall be applicable to students admitted to the B.Sc. (Hons.) Statistics programme:

a) A student who appears in an odd semester examinations or who was eligible to appear in the odd semester examinations but remains absent in any or all the papers of the said semester, shall move on to the next even semester irrespective of his/her result in the said examinations.

b) A student who has obtained 40% on the aggregate taking together all the papers in theory examination (including internal assessment) and practical examination conducted in Ist and IInd semester shall be promoted to the second academic year/IIIrd semester.

c) A student who has obtained 40% on the aggregate taking together all the papers in theory examination (including internal assessment) and practical examinations conducted in IIIrd and IVth semester shall be promoted to the third academic year/ Vth semester.

d) Students who do not fulfill the promotion criteria mentioned above shall be declared fail in the promotion examination of the academic year concerned. However, they shall have the option to retain the marks in the papers in which they want to retain.

e) If a student has secured an aggregate of minimum 40% marks taking together all the papers in theory examination (including internal assessment) and practical examination till the end of the third year, i.e., upto the end of the VIth semester, then she/he shall be awarded the degree in which the student has been admitted.

f) A student who wants to re-appear for improvement in marks in a paper prescribed for semester I/III/V may do so only in the semester examinations to be held in November/December. A student who wants to re-appear for improvement in a paper

prescribed in semester II/IV/VI may do so only in the examinations to be held in May/June.

10.2 Semester to Semester Progression:

a) A student may re-appear in any theory paper prescribed for a semester, on foregoing in writing her/his previous performance in the paper/s concerned. This can be done in the odd/even semester examination only (for example , a student reappearing in paper prescribed for semester I examination may do so along with subsequent semester IIIrd examination and not along with papers for semester Vth).

b) A candidate who has cleared examinations of third academic year (Vth and VIth semesters) may re-appear in any paper of V or VI semester only once, at the odd/even examinations on foregoing in writing her/his previous performance in the paper/s concerned, within the prescribed span period. (Note: The candidate of this category will not be allowed to join any post-graduate courses).

c) In the case of re-appearance in paper, the result will be prepared on the basis of candidate's current performance in the examinations.

d) In the case of a candidate, who opts to re-appear in any paper/s under the aforesaid provisions, on surrendering her/his earlier performance but fails to reappear in the paper/s concerned, the marks previously secured by the candidate in the paper/s in which she/he has failed to re-appear shall be taken into account while determining her/his result of the examination held currently.

e) Re-appearance in practical/internal assessment shall not be allowed.

f) Duration of end semester theory examinations of Core and Elective subjects shall be three hours.

g) The entire evaluation process for AECC and Skill Enhancement Courses (SEC) shall be undertaken by each college where the AECC and SEC are being taught and the teacher responsible for the conduct of learning of the AECC and SEC shall be responsible for the evaluation.

10.3 Span Period

No student shall be admitted as a candidate for the examination for any of the Parts/Semesters after the lapse of five years from the date of admission to the Part-I/Semester-I of the B.Sc. (Hons.) Statistics Programme.

10.4 Grade Points

A student who becomes eligible for the degree shall be categorized on the basis of the combined result of semester I to semester VI examinations under CBCS on a 10 point grading system with the letter grades. Grade point table as per university examination rules.

10.5 CGPA Calculation

As per university examination rules.

10.6 SGPA Calculation

As per university examination rules.

10.7 Grand SGPA Calculation

As per university examination rules.

10.8 Conversion of Grand CGPA into Marks

As notified by competent authority the formula for conversion of Grand CGPA into marks is: Final %age of marks = CGPA based on all four semesters × 9.5.

10.9 Division of Degree into Classes

As per university examination rules.

10.10 Attendance Requirement

As per university examination rules.

10.11 Guidelines for the Award of Internal Assessment Marks B.Sc. (Hons.) Statistics Programme (Semester Wise)

As per university examination rules.

11. Course Wise Content Details for B.Sc. (Hons.) Statistics Programme

Core Papers in Statistics

Bachelor of Science (Hons.) in Statistics
Semester I
STAT-C-101: Descriptive Statistics

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:

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

Course Learning Outcomes:
After completing this course, the students should have developed a clear understanding of:

- Concepts of statistical population and sample, variables and attributes.
- Tabular and graphical representation of data based on variables.
- 'Conditions for the consistency' and criteria for the independence of data based on attributes.
- Measures of central tendency, Dispersion, Skewness and Kurtosis.
- Moments and their use in studying various characteristics of data.
- Different approaches to the theory of probability.
- Important theorems on probability and their use in solving problems.
- Concept of random variables and its probability distributions.
- Concept of joint, marginal and conditional probability distribution for two dimensional random variables and their independence.
- Univariate transformation and expectation of random variables.

Contents:

UNIT 1

Statistical Methods: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement-nominal, ordinal, interval and ratio. Presentation: tabular and graphical, including histogram and Ogives, Theory of attributes: consistency and independence of data with special reference to attributes.

UNIT II

Measures of Central Tendency: Mathematical and positional, partition values, Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, Moments, absolute moments, factorial moments, skewness and kurtosis,

Sheppard's corrections.

UNIT III

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability-classical, statistical, and axiomatic.Conditional Probability, Addition and multiplication theorem of probability, independent events, Theorem of Total probability, Bayes' theorem and its applications.

UNIT IV

Random variables: discrete and continuous, illustrations and properties of random variables, pmf, pdf and cdf, Two dimensional random variables: Joint, marginal and conditional pmf/pdf, independence of random variables. Univariate transformation. Mathematical Expectation: Expectation of random variables and its properties.

SUGGESTED READINGS:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). *Fundamentals of Statistics*, Vol. I, 8th Ed. The World Press, Kolkata.
2. Miller, I. and Miller, M. (2006). *John E. Freund's Mathematical Statistics with Applications*, 7th Ed., Pearson Education, Asia.
3. Mood, A.M., Graybill, F.A. and Boes, D.C. (2007). *Introduction to the Theory of Statistics*, 3rd Ed., (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
4. Ross, S.M. (2002). *A first course in Probability,* 6th Ed., Pearson.
5. Ross, S. M. (2010). *Introductory statistics,* 3rd Ed., Academic Press.

PRACTICAL/LAB WORK
List of Practicals

1. Presentation of data in:
   a) Discrete & Continuous frequency table
   b) Cumulative frequency table
2. Graphical representation of data-
   a) Frequency curve, frequency polygon and histogram
   b) Ogives
3. Measures of Central tendency:
   a) Based on Arithmetic mean:
   - Formulae (Direct Method)
   - Change of Origin and Scale

   b) Based on Median and partition values:
   - Formulae (Direct Method)
   - Graphically

   c) Based on Mode:

- Formulae (Direct Method)
- Graphically
- By the method of grouping

4. Measures of Dispersion -
   a) Quartile deviation using formula and graphically
   b) Mean Deviation
   c) Standard deviation and variance:
   - Formulae (direct method)
   - Change of origin & Scale
5. Coefficient of dispersion and variation
6. Combined mean and combined variance
7. Raw moments
8. Moments about any arbitrary point
9. Central Moments
10. Moments using relation between Raw moments, Moments about any arbitrary point and Central Moments
11. Correct moments involving wrong data
12. Skewness based on mean, median, mode and standard deviation
13. Skewness and kurtosis based on moments
14. Problem based on missing frequencies
15. Theory of attributes-
    a) Representation of word problems in the form of class frequencies
    b) Based on Fundamental set of class frequencies
    c) Association and independence of attributes.

Week –wise Teaching Plan

Week 1	Definition and scope of Statistics, concepts of statistical population and sample.Data: quantitative and qualitative, attributes, variables, scales of measurement-nominal, ordinal, interval and ratio.
Week 2	Tabular and graphical presentation, including histogram and Ogives.
Week 3	Theory of attributes, consistency and independence of data with special reference to attributes.
Week 4	Mathematical and positional measures of Central Tendency, Partition values.
Week 5	Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation.
Week 6	Moments, absolute moments, factorial moments, skewness and kurtosis, Sheppard's corrections.
Week 7	Probability introduction, random experiments, sample space, events and algebra of events.

Week 8	Classical, statistical, and axiomatic definitions of Probability, Conditional Probability.
Week 9	Addition and multiplication theorem of probability, independent events, Theorem of Total probability.
Week 10	Bayes' theorem and its applications.
Week 11	Discrete and continuous random variables, illustrations and properties of random variables.
Week 12	pmf, pdf and cdf.
Week 13	Two dimensional random variables: Joint, marginal and conditional pmf/pdf.
Week 14	Independence of random variables. Univariate transformations.
Week 15	Expectation of random variables and its properties.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Concepts of statistical population and sample, variables and attributes.	Classroom lectures and discussions.	Participation in class discussions.
I	Tabular and graphical representation of data based on variables.	(i) Classroom lectures and discussions. (ii) Practical work.	Participation in class discussions. Ability to apply concepts in practical examples.
I	'Conditions for the consistency' and criteria for the independence of data based on attributes.	(i)Classroom lectures and discussions. (ii) Practical work.	Participation in class discussions. Ability to apply concepts in practical examples.
II	Measures of central tendency, Dispersion, Skewness and Kurtosis.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussions. Ability to apply concepts in practical examples.
II	Moments and their use in studying various characteristics of data.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussions. Ability to apply concepts in practical examples.
			Class test/assignment on first two units
III	Different approaches to the theory of probability.	Classroom lectures and discussions.	Participation in class discussions.
III	Important theorems on probability and their use in solving problems.	Classroom lectures and discussions	Participation in class discussions.

IV	Concept of random variables and its probability distributions.	Classroom lectures and discussions.	Participation in class discussions.
IV	Concept of joint, marginal and conditional probability distribution for two dimensional random variables and their independence.	Classroom lectures and discussions.	Participation in class discussions.
IV	Univariate transformation and expectation of random variables.	Classroom lectures and discussions.	Participation in class discussions.
			Class test/assignment on last two units.

Keywords: Mathematical and positional measures of Central Tendency, Measures of Dispersion, Probability introduction, Theory of attributes, Bayes' theorem Discrete and continuous random variables.

Bachelor of Science (Hons.) in Statistics

Semester I

STAT-C-102: CALCULUS

Credits: 6 **Marks: 100**

Course Objectives:

The learning objectives include:

- Fundamentals of differential calculus/Integral calculus/Differential Equation/Partial differential equation.
- To analyse the problem and its solution.

Course Learning Outcomes:

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

- The fundamental concepts of Differential calculus.
- Solving complicated integrals.
- Finding complete Solution of differential equations.
- Searching solution of partial differential equation.

UNIT I

Differential Calculus**:** Limits of function, continuous functions, properties of continuous functions, partial differentiation and total differentiation. Indeterminate forms: L-Hospital's rule, Leibnitz rule for successive differentiation. Euler's theorem on homogeneous functions. Maxima and minima of functions of one and two variables, constrained optimization techniques (with Lagrange multiplier) along with some problems. Jacobian, concavity and convexity, points of inflexion of function, singular points. Theory of asymptotes (Only for cartisian forms).

UNIT II

Integral Calculus**:** Review of integration and definite integral. Differentiation under integral sign, double integral, change of order of integration, transformation of variables. Beta and Gamma functions: properties and relationship between them.

UNIT III

Differential Equations**:** Exact differential equations, Integrating factors, change of variables, Total differential equations, Differential equations of first order and first degree, Differential equations of first order but not of first degree, Equations solvable for x, y, q, Equations of the first degree in x and y, Clairaut's equations. Higher Order Differential Equations**:** Linear differential equations of order n, Homogeneous and non-homogeneous linear differential equations of order n with constant coefficients, Different forms of particular integrals, Linear differential equations with non-constant coefficients, Reduction of order method, The Cauchy-Euler's equation of order n, Legendre's linear equation.

UNIT IV

Formation and solution of a partial differential equations**.** Equations easily integrable. Linear partial differential equations of first order. Non-linear partial differential equation of first order and their different forms. Charpit's method. Homogeneous linear partial differential equations with constant coefficients. Different cases for complimentary functions and particular integrals.

SUGGESTED READINGS:

1. Prasad, G. (1997). *Differential Calculus*, 14th Ed., Pothishala Pvt. Ltd., Allahabad.
2. Prasad, G. (2000). *Integral Calculus*, 14th Ed., Pothishala Pvt. Ltd., Allahabad.
3. Ahsan, Z. (2004). *Differential Equations and their Applications*, 2nd Ed., Prentice-Hall of India Pvt. Ltd., New Delhi.

PRACTICAL/LAB WORK: NO PRACTICALS

Week-wise Teaching Plan:

Week 1	Limits of function, continuous functions. Properties of continuous functions.
Week 2-3	Partial differentiation and total differentiation. Indeterminate forms: L-Hospital's rule.
Week 4	Leibnitz rule for successive differentiation. Euler's theorem on homogeneous functions.
Week 5	Maxima and minima of functions of one and two variables, constrained optimization techniques (with Lagrange multiplier) along with some problems.
Week 6	Jacobian, concavity and convexity, points of inflexion of function, singular points. Theory of Asymptotes (Only for Cartesian forms).
Week 7	Integral Calculus: Review of integration and definite integral. Differentiation under integral sign.
Week 8	Double integral, change of order of integration, transformation of variables.
Week 9	Beta and Gamma functions: properties and relationship between them.
Week 10	Differential Equations: Exact differential equations, Integrating factors, change of variables, Total differential equations, Differential equations of first order and first degree, Differential equations of first order but not of first degree, Equations solvable for x, y, q, Equations of the first degree in x and y, Clairaut's equations.
Week 11	Higher Order Differential Equations: Linear differential equations of order n, Homogeneous and non-homogeneous linear differential equations of order n with constant coefficients, Different forms of particular integrals.
Week 12	Linear differential equations with non-constant coefficients, Reduction of order method. The Cauchy-Euler's equation of order n, Legendre's linear equation.
Week 13	Formation and solution of a partial differential equations**.** Equations easily integrable. Linear partial differential equations of first order. Non-linear partial differential equation of first order and their different forms. Charpit's method.
Week 14-15	Homogeneous linear partial differential equations with constant coefficients. Different cases for complimentary functions and particular integrals.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Limits of function, continuous functions. Properties of continuous functions.	Class room lectures and discussions.	Participation in class discussion and problem solving.
I	Partial differentiation and total differentiation. Indeterminate forms: L-Hospital's rule.		
I	Leibnitz rule for successive differentiation. Euler's theorem on homogeneous functions.		
I	Maxima and minima of functions of one and two variables, constrained optimization techniques (with Lagrange multiplier) along with some problems.		
I	Jacobian, concavity and convexity, points of inflexion of function, singular points. Theory of Asymptotes (Only for Cartesian forms).		
II	Integral Calculus: Review of integration and definite integral. Differentiation under integral sign.	Class room lectures and discussions.	Participation in class discussion and problem solving.
II	Double integral, change of order of integration, transformation of variables.		
II	Beta and Gamma functions: properties and relationship between them.		
III	Differential Equations: Exact differential equations, Integrating factors, change of variables, Total differential equations, Differential equations of first order and first degree, Differential equations of first order but not of first degree, Equations solvable for x, y, q, Equations of the first degree in x and y, Clairaut's equations.	Class room lectures and discussions.	Participation in class discussion and problem solving.
III	Higher Order Differential Equations: Linear differential equations of order n, Homogeneous and non-homogeneous linear differential equations of order n with constant coefficients, Different forms of particular integrals.		
III	Linear differential equations with non-constant coefficients, Reduction of order method. The Cauchy-Euler's equation of order n, Legendre's linear equation.		
IV	Formation and solution of a partial differential equations**.** Equations easily integrable. Linear partial differential equations of first order. Non-linear partial differential equation of first	Class room lectures and discussions.	Participation in class discussion

	order and their different forms. Charpit's method		and problem solving.
IV	Homogeneous linear partial differential equations with constant coefficients. Different cases for complimentary functions and particular integrals.		

Keywords: Limits of function, L-Hospital's rule, Jacobian, concavity and convexity, Differentiation under integral sign, Exact differential equations, Higher Order Differential Equations, Formation and solution of a partial differential equations, Homogeneous linear partial differential equations with constant coefficients.

Bachelor of Science (Hons.) in Statistics
Semester II
STAT-C-201: Probability and Probability Distributions

Credits: 6 **Marks:150**

Course Objective:
The purpose is to familiarize the students about the basic concepts required for further studies of advanced curriculum.

Course Learning Outcomes:
After completing this course, there should be a clear understanding of:
- The fundamental concept of expectation for univariate and bivariate random variables with their distributions and properties.
- Moment generating function, cumulant generating function and characteristic function.
- Discrete probability distributions with their properties.
- Continuous probability distributions with their properties.

Contents:

UNIT I

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

UNIT II

Bivariate data: Definition, scatter diagram, Karl Pearson's coefficient of correlation. Spearman's rank correlation coefficient. Principle of least squares and fitting of polynomials and exponential curves. Linear regression. Partial and multiple correlation (3 variables only).

UNIT III

Discrete Probability Distributions: Uniform, Binomial, Poisson, Geometric, Negative Binomial and Hyper-geometric distributions along with their characteristic properties and limiting/approximation cases.

UNIT IV

Continuous probability distributions: Normal, Exponential, Uniform, Beta, Gamma, Cauchy, lognormal and Laplace distributions along with their characteristic properties and limiting/approximation cases.

SUGGESTED READINGS:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). *Fundamentals of Statistics*, Vol. I, 8th Ed., The World Press, Kolkata.
2. Hogg, R.V., Tanis, E.A. and Rao, J.M. (2009). *Probability and Statistical Inference*, 7th Ed., Pearson Education, New Delhi.
3. Miller, I. and Miller, M. (2006). *John E. Freund's Mathematical Statistics with Applications*, 8th Ed., Pearson Education, Asia.
4. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007). *Introduction to the Theory of Statistics*, 3rd Ed., (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

PRACTICAL/LAB WORK
List of Practicals

1. Fitting of polynomials, exponential curves.
2. Karl Pearson correlation coefficient.
3. Correlation coefficient for a bivariate frequency distribution.
4. Lines of regression, angle between lines and estimated values of variables.
5. Spearman rank correlation with and without ties.
6. Partial and multiple correlations.
7. Planes of regression and variances of residuals for given simple correlations.
8. Fitting of binomial distributions.
9. Fitting of Poisson distributions.
10. Fitting of negative binomial distribution.
11. Fitting of suitable distribution.
12. Application problems based on binomial distribution.
13. Application problems based on Poisson distribution.
14. Application problems based on negative binomial distribution.
15. Problems based on area property of normal distribution.
16. To find the ordinate for a given area for normal distribution.
17. Application based problems using normal distribution.
18. Fitting of normal distribution.

Week-wise Teaching plan

Mathematical Expectation	
Week 1	Variance and covariance of random variables and their properties, Conditional expectations.
Week 2	Bivariate transformations with illustrations.
Weeks 3-4	Moments, moment generating function and its properties. Cumulants, cumulant generating function and its properties. Characteristic function and its properties. Inversion theorem for continuous random variables (without proof) along with applications.
Bivariate Data	
Week 5	Definition, scatter diagram, Karl Pearson's coefficient of correlation. Spearman's rank correlation coefficient. Practical work
Week 6	Principle of least squares and fitting of polynomials and exponential curves.

	Practical work
Week 7	Linear regression. Partial and multiple correlation (3 variables only). Practical work
Discrete Probability distributions along with their characteristic properties and limiting/approximation cases.	
Week 8-9	Binomial and Poisson distributions. Practical work
Week 9-10	Uniform, Geometric, Negative Binomial distributions.
Week 11	Hypergeometric distributions.
Continuous probability distributions along with their characteristic properties and limiting/approximation cases.	
Week 12-13	Uniform, Normal and lognormal distribution. Practical work
Week 14-15	Exponential, Beta, Gamma, Cauchy & Laplace Distribution.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction of variance, covariance, conditional expectation with their related properties.	Class room lectures and discussions.	Participation in class discussion.
I	Concept bivariate transformations with illustrations for discrete as well as continuous random variables.	Class room lectures and discussions.	Participation in class discussion.
I	Moments, moment generating function, cumulants, cumulant generating function and characteristic function and their relationship with properties.	Class room lectures and discussions.	Participation in class discussion and quiz (optional).
A*	Understanding of above basic concepts used in statistics.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
II	Understanding of bivariate data through scatter diagram and correlation coefficients (Karl pearson& Spearman's rank).	(i)Class room lectures and discussions. (ii) Practical work.	Participation in class discussion with identification of different types of correlation coefficients.
II	Fitting of polynomials and curves using method of least squares.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion and surprise test (optional).
II	Linear regression, multiple	(i) Class room	Participation in class

	and partial correlation.	lectures and discussions. (ii) Practical work.	discussions.
III	Discrete probability distributions: Bernoulli, Binomial, Poisson, Geometric, Negative Binomial, Uniform and hypergeometric distributions.	(i) Class room lectures and discussions. (ii)Practical work.	Participation in class discussion. How Binomial is obtained from Bernoulli distribution and the limiting cases of all the distributions.
IV	Continous probability distributions: Uniform Normal, log normal, exponential Gamma, Beta, Cauchy and Laplace.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion and limiting distribution towards normal distribution.
B*	Understanding of different types of correlations and regressions.	Class Test/ Assignment work.	
C*	Understanding of applications for Binomial, Poisson, Negative Binomial and normal distribution.	Class Test/ Assignment work for practical.	
D*	Understanding of discrete and continuous distributions.	Class Test/ Assignment work.	Ability to apply different distributions.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Variance and covariance of random variables and their properties, Conditional expectations, Bivariate transformations with illustrations, Moments generating function, Bivariate Data, Karl Pearson's coefficient of correlation, fitting of polynomials and exponential curves, Discrete and Continuous Probability distributions along with their characteristic properties and limiting/approximation cases.

Bachelor of Science (Hons.) in Statistics
Semester II
STAT C-202: Algebra

Credits: 6 **Marks: 150**

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

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

- Theory of Equations
- The fundamental concepts of matrices and determinants
- Echelon form
- Linear equations
- Rank of a Matrix
- Characteristic roots and vectors
- Quadratic forms
- Partitioning of matrices
- Generalized inverse

Contents:

UNIT I

Theory of equations, statement of the fundamental theorem of algebra and its consequences. Relation between roots and coefficients or any polynomial equations. Solutions of cubic and biquadratic equations when some conditions on roots of equations are given. Evaluation of the symmetric polynomials and roots of cubic and biquadratic equations. Vector spaces, Subspaces, sum of subspaces, Span of a set, Linear dependence and independence, dimension and basis, dimension theorem.

UNIT II

Algebra of matrices - A review, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, Hermitian and skew Hermitian matrices, orthogonal matrices, singular and non-singular matrices and their properties. Trace of a matrix, unitary, involutory and nilpotent matrices. Adjoint and inverse of a matrix and related properties.

UNIT III

Determinants of Matrices: Definition, properties and applications of determinants for 3rd and higher orders, evaluation of determinants of order 3 and more using transformations. Symmetric and Skew symmetric determinants, Circulant determinants, Jacobi's Theorem, product of determinants. Use of determinants in solution to the system of linear equations, row reduction and echelon forms, the matrix equations AX=B, solution sets of linear equations, linear independence, Applications of linear equations, inverse of a matrix.

UNIT IV

Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Generalized inverse (concept with illustrations). Partitioning of matrices and simple properties. Characteristic roots and Characteristic vector, Properties of characteristic roots, Cayley Hamilton theorem, Quadratic forms, Linear orthogonal transformation and their digitalization.

SUGGESTED READINGS:

1. Artin M. (1994). *Algebra*. Prentice Hall of India.
2. Biswas, S. (1997). *A Textbook of Matrix Algebra*, New Age International.
3. Gupta, S.C. (2008). *An Introduction to Matrices (Reprint).* Sultan Chand & Sons.
4. Hadley, G. (2002). *Linear Algrbra*. Narosa Publishing House (Reprint).
5. Jain, P.K. and Ahmad, K. (1973). *Metric Spaces*, Narosa Publishing House, New Delhi.
6. Krishnamurthy, V., Mainra, V.P. and Arora, J.L. (2015). *An Introduction to Linear Algebra*, East West Press Pvt. Ltd., New Delhi.
7. Lay, D. C. (2000). *Linear Algebra and its Applications*, Addison Wesley.
8. Searle, S.R. (1982). *Matrix Algebra Useful for Statistics*. John Wiley &Sons.

PRACTICAL/LABWORK
List of Practicals:

1. Finding inverse using Cayley Hamilton theorem.
2. For a real Skew Symmetric matrix S, show that matrix A defined by (I-S) (I+S)-1 is an orthogonal matrix.
3. Reducing a Quadratic Form to its canonical form and finding its rank and index.
4. Proving that a quadratic form is positive or negative definite.
5. Finding the product of two matrices by considering partitioned matrices.
6. Finding inverse of a matrix by partitioning.
7. Finding Generalized Inverse of a matrix and symmetric generalized inverse of a matrix
8. To show that matrix A defined as A= (In - X $(X'X)^{-1}X'$) is idempotent. Also, determine its rank and characteristic root. Repeat the process by finding a generalized inverse of X'X if inverse does not exist.
9. Find XGX' for any X of order nxk, where G is generalized inverse and show that XGX' is invariant with respect to G.
10. To find whether a given set of vectors is linearly dependent or linearly independent.
11. Constructing an Orthonormal Basis using Gram Schmidt Orthogonalization Process.

Week –wise Teaching Plan:

Week 1	Statement of the fundamental theorem of algebra and its consequences. Relation between roots and coefficients or any polynomial equations.
Week 2	Solutions of cubic and biquadratic equations when some conditions on roots of equations are given. Evaluation of the symmetric polynomials and

	roots of cubic and biquadratic equations.
Week 3-4	Review of algebra of matrices, theorems related to triangular, symmetric and skew symmetric matrices, idempotent matrices, Hermitian and skew Hermitian matrices, orthogonal matrices, singular and non-singular matrices and their properties. Trace of a matrix, unitary, involutory and nilpotent matrices. Practical work.
Week 5	Adjoint and inverse of a matrix and related properties. Practical work.
Week 6-7	Definition, properties and applications of determinants for 3rd and higher orders, evaluation of determinants of order 3 and more using transformations. Symmetric and Skew symmetric determinants, Circulant determinants, Jacobi's Theorem, product of determinants. Use of determinants in solution to the system of linear equations.
Week 8-9	Row reduction and echelon forms, the solution of matrix equations AX=B, linear independence, Applications of linear equations, inverse of a matrix. Practical work.
Week 10	Rank of a matrix, row-rank, column-rank, standard theorems on ranks, rank of the sum and the product of two matrices. Practical work.
Week 11	Generalized inverse (concept with illustrations). Practical work.
Week 12	Partitioning of matrices and simple properties. Practical work.
Week 13-14	Characteristic roots and Characteristic vector, Properties of characteristic roots, Cayley Hamilton theorem. Practical work.
Week 15	Quadratic forms, Linear orthogonal transformation and their digitalization. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Theory of Equations.	Class room lectures.	Solving problems.
II, III	The fundamental concepts of matrices and determinants.	Class room lectures with practical work.	Solving problems.
III	Echelon form, Linear equations.	Class room lectures with practical work.	Solving problems.
IV	Rank of a Matrix, Characteristic roots and vectors, Quadratic forms.	Class room lectures with practical work.	Class test*.
IV	Partitioning of matrices.	Class room lectures with practical work.	Assignment* work on different kinds of partitioned matrices.
IV	Generalized inverse.	Class room lectures with practical work.	Identification of cases for application.

*As per the requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Theory of Equations, The fundamental concepts of matrices and determinants, Echelon form, Linear equations, Rank of a Matrix, Characteristic roots and vectors,

Quadratic forms Partitioning of matrices, Generalized inverse.

Bachelor of Science (Hons.) in Statistics
Semester III
STAT-C-301: Sampling Distributions

Credits: 6 **Marks: 150**

Course Objectives:

The learning objectives include:

- To understand the concept of sampling distributions and their applications in statistical inference.
- To understand the process of hypothesis testing.
- To have a clear understanding of when to apply various tests of hypothesis about population parameters using sample statistics and draw appropriate conclusions from the analysis.

Course Learning Outcomes:

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

- Laws of convergence, their inter relations and applications.
- Central Limit Theorem and its applications.
- Order statistics and distribution of sample median and range.
- Basic concepts of hypothesis testing, including framing of null and alternative hypothesis.
- Hypothesis testing based on a single sample and two samples using both classical and p value approach.
- Chi square distribution.
- Analyze categorical data by using Chi square techniques.
- t and F distributions and their applications.

Contents:

UNIT I

Limit laws: convergence in probability, almost sure convergence, convergence in mean square and convergence in distribution and their inter relations, Chebyshev's inequality, W.L.L.N., S.L.L.N. and their applications, De-Moivre Laplace theorem, Central Limit Theorem (C.L.T.) for i.i.d. variates, applications of C.L.T. and Liapunov Theorem (without proof). Order Statistics: Introduction, distribution of the rth order statistic, smallest and largest order statistics. Joint distribution of rth and sth order statistics, distribution of sample median and sample range.

UNIT II

Definitions of random sample, parameter and statistic, sampling distribution of a statistic, sampling distribution of sample mean, standard errors of sample mean, sample variance and sample proportion. Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region. Large sample tests, use of CLT for testing

single proportion, difference of two proportions, single mean, difference of two means, standard deviation and difference of standard deviations by classical and p-value approaches.

UNIT III

Exact sampling distribution: Definition and derivation of pdf of $\chi 2$ with n degrees of freedom (d.f.) using mgf, nature of pdf curve for different degrees of freedom, mean, variance, mgf, cumulant generating function, mode, additive property and limiting form of $\chi 2$ distribution. Tests of significance and confidence intervals based on χ^2 distribution.

UNIT IV

Exact sampling distributions: Student's and Fishers t-distribution, Derivation of its pdf, nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of t distribution. Derivation of distribution of sample correlation coefficient when population correlation coefficient is zero (Sawkin's Methods).Snedecore's F-distribution: Derivation of pdf, nature of pdf nature of pdf curve with different degrees of freedom, mean, variance and mode. Distribution of 1/F(n1,n2). Relationship between t, F and $\chi 2$ distributions. Test of significance and confidence Intervals based on t and F distributions.

SUGGESTED READINGS:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2003). *An Outline of Statistical Theory*, Vol. I, 4th Ed., World Press, Kolkata.
2. Hogg, R.V. and Tanis, E.A. (2009). *A Brief Course in Mathematical Statistics*. Pearson Education.
3. Johnson, R.A. and Bhattacharya, G.K. (2001). *Statistics-Principles and Methods*, 4th Ed., John Wiley and Sons.
4. Mood, M.A., Graybill, F.A. and Boes, C.D. (2007). *Introduction to the Theory of Statistics*, 3rd Ed., (Reprint).Tata McGraw-Hill Pub. Co. Ltd.
5. Rohatgi, V. K. and Saleh, A.K. Md. E. (2009). *An Introduction to Probability and Statistics*, 2nd Ed., (Reprint) John Wiley and Sons.

PRACTICAL/LAB WORK
List of Practicals

1. Large Sample Tests:

a) Testing of significance and confidence intervals for single proportion and difference of two proportions.
b) Testing of significance and confidence intervals for single mean and difference of two means.
c) Testing of significance and confidence intervals for difference of two standard deviations.

2. Tests based on Chi-Square Distribution:

   a) To test if the population variance has a specific value and its confidence intervals.
   b) To test the goodness of fit.
   c) To test the independence of attributes.
   d) Test based on 2 X 2 contingency table without and with Yates' corrections.
   e) To test the homogeneity of independent estimates of population correlation coefficient.

3. Tests based on t- Distribution and F- Distribution:

   a) Testing of significance and confidence intervals for single mean and difference of two means and paired t – test.
   b) Testing of significance and confidence intervals of an observed sample correlation coefficient.
   c) Testing and confidence intervals of equality of two population variances.
   d) Testing of significance of an observed multiple correlation coefficients.

Week –wise Teaching Plan

Week 1-2	Limit laws, different types of convergence and their inter relations, Central Limit Theorem (CLT), applications and examples based on CLT.
Week 3–4	Order statistics: distribution of r^{th} order, largest and smallest order statistics and joint distribution of two order statistics, distribution of sample median and range. Examples based on theory.
Week 5	Sampling distributions: definition of parameter, statistic, standard error and their concepts, Sampling distribution of various statistics.
Week 6	Introduction to hypothesis testing (classical and p value approach): formulation of null and alternative hypothesis, Type I and Type II errors, level of significance and critical region. Examples based on these.
Week 7-8	Large sample tests: for single mean, single proportion, difference of two means, difference of two proportions, difference of two standard deviations all with examples. Examples and practical work based on these tests.
Week 9-11	Chi square distribution: Definition and derivation of pdf of $\chi 2$ with n degrees of freedom (d.f.) using mgf, nature of pdf curve for different degrees of freedom, mean, variance, mgf, cumulant generating function, mode, additive property and limiting form of $\chi 2$ distribution. Tests of significance and confidence intervals based on Chi-Square Distribution. Includes examples and practical work.
Week12-13	Student's and Fishers t-distribution: Derivation of pdf, nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of the distribution, Distribution of sample correlation coefficient when population correlation coefficient is zero. Tests of significance and confidence intervals based on t distribution. Includes examples and practical work.
Week14-15	Distribution of F statistic: derivation of pdf, nature of probability curve with different degrees of freedom, mean, variance, moments, mode and limiting form of the distribution, points of inflexion. Distribution of 1/F(n1,n2). Relationship between t, F and $\chi 2$ distributions. Test of significance and confidence intervals based on F distribution. Includes examples and practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	The laws of convergence, Central Limit Theorem and its applications.	Class room lectures and discussions.	Participation in class discussion.
I	Order statistics and distribution of sample median and range.	Class room lectures and discussions.	Participation in class discussion.
II	Introduction to sampling distributions.	Class room lectures and discussions.	Participation in class discussion.
II	Basic concepts of hypothesis testing.	Class room lectures and discussions.	Participation in class discussion.
II	Large sample tests using classical and p value approach.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion. Ability to apply concepts in practical examples.
			Class test/assignment on first two units.
III	Chi square distribution: definition, derivation of its pdf and properties.	(i)Class room lectures and discussions. (ii) Practical work.	Participation in class discussion. Ability to apply concepts in practical examples.
III	Tests of significance and confidence intervals based on χ^2 distribution.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion. Ability to apply concepts in practical examples.
IV	Student's t distribution and its applications.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion. Ability to apply concepts in practical examples.
IV	F distribution and its applications.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion. Ability to apply concepts in practical examples.
			Class test/assignment on last two units.

Keywords: Law of large numbers, Sampling distribution, Tests of significance, Hypotheses, Critical region, p-value, Order statistics.

Bachelor of Science (Hons.) in Statistics
Semester III
STAT-C-302: Survey Sampling and Indian Official Statistics

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To provide tools and techniques for selecting a sample of elements from a target population keeping in mind the objectives to be fulfilled and nature of population.
- To obtain estimator of the population parameter on the basis of selected sample and study its properties.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- The fundamental concepts of population and sample. (or The basic concepts of survey)
- The principles of sample survey and the steps involved in selecting a sample.
- Simple Random Sampling.
- Stratified Sampling.
- Systematic Sampling.
- Ratio and Regression Methods of Estimation.
- Cluster Sampling (equal size clusters).
- Sub Sampling.
- Indian Official Statistics.

Contents:

UNIT I

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination.

UNIT II

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance, Collapsed Strata. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates ($N = n \times k$). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections. Circular systematic sampling (only definition).

UNIT III

Introduction to Ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size), variances of these estimates and estimates of these variances, variances in terms of correlation coefficient for regression method of estimation and their comparison with SRS. Cluster sampling (equal clusters only) estimation of population mean and its variance, comparison (with and without randomly formed clusters). Relative efficiency of cluster sampling with SRS in terms of intra class correlation. Concept of sub sampling.

UNIT IV

Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population, industry and finance.

SUGGESTED READINGS:

1. Cochran, W.G. (2011). *Sampling Techniques*, 3rd Ed., Wiley Eastern John Wiley and Sons.
2. Raj, D. and Chandhok, P. (1998). *Sample Survey Theory*, Narosa Publishing House.
3. Goon, A. M., Gupta, M. K. and Dasgupta, B. (2001). *Fundamentals of Statistics*, Vol.2, World Press.
4. *Guide to current Indian Official Statistics, Central Statistical Office*, GOI, New Delhi.
5. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand.
6. mospi.nic.in/nscr/iss.html.
7. Murthy M.N. (1977). *Sampling Theory & Statistical Methods*, Statistical Pub. Society, Calcutta.
8. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S., Asok, C.(1984). *Sampling Theories of Survey with Application*, IOWA State University Press and Indian Society of Agricultural Statistics.
9. Singh, D. and Chaudhary, F. S. (2015). *Theory and Analysis of Sample Survey Designs.*
10. www.emathzone.com/tutorials/basics-statistics/collection-of-stastical-data.htm.l
11. https://cyfars.org/data-collection-technique.

PRACTICAL/LAB WORK
List of Practicals:

1. To select SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square and

population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.

3. For SRSWOR, estimate mean, standard error, the sample size.
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods Compare the efficiencies of above two methods relative to SRS.
5. Estimation of gain in precision in stratified sampling.
6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend and using end's correction.
7. Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS.
8. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS.

Week-wise Teaching Plan

Week 1-2	Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey.
Week 3-4	Simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination. Practical work.
Week 5-7	Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance, Collapsed strata. Practical work.
Week 8	Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates ($N = n \times k$). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections. Circular systematic sampling (only definition). Practical work.
Week 9-10	Introduction to ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size), variances of these estimates and estimates of these variances, variances in terms of correlation coefficient for regression method of estimation and their comparison with SRS. Practical work.
Week 11-12	Cluster sampling (equal clusters only) estimation of population mean and its variance, comparison (with and without randomly formed clusters). Relative efficiency of cluster sampling with SRS in terms of intra class correlation. Concept of sub sampling. Practical work.
Week 13-15	Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population, industry and finance.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Basic concepts of survey.	Class room lectures and discussions.	Participation in class discussion.
I	Principles of sample survey and steps involved in selecting a sample.	Class room lectures and discussions.	Participation in class discussion.
I	Simple Random Sampling.	(i) Class room lectures and discussions. (ii) Practical work based on the design and analysis.	(i) Participation in class discussion. (ii)Applying appropriate sampling technique to draw sample and obtaining estimates of the population parameters. Interpretation and comparison of results and conclusions.
II	Stratified Sampling.		
A*	Understanding of basic concepts and techniques.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
II	Systematic Sampling.	(i) Class room lectures and discussions. (ii) Practical work based on the design and analysis.	(i) Participation in class discussion. (ii)Applying appropriate sampling technique to draw sample and obtaining estimates of the population parameters. Interpretation and comparison of results and conclusions.
III	Ratio and Regression methods of estimation.		
III	Cluster Sampling and Sub sampling.		
IV	Indian Official Statistics.	Class room lectures and discussions.	Participation in class discussion and presentation.
B*	Understanding of various techniques of sampling and Indian official statistics.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
C	Application of Survey Sampling. (optional)	Project work and its presentation.	Ability to apply concepts of sampling and obtain the required estimates of the population parameters.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Population and sample, Simple Random Sampling, Stratified Sampling, Ratio and regression methods of estimation, Cluster Sampling, Indian Official Statistics

Bachelor of Science (Hons.) in Statistics
Semester III
STAT-C-303: Mathematical Analysis

Credits: 6 **Marks:150**

Course Objectives:
The learning objectives include:
- To study the Real Analysis, this deals with the analytical properties of real functions and sequences.
- To study the Numerical Analysis, this is the study of algorithms that use numerical approximation for the problems of mathematical analysis.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- Fundamental properties of real number and real-valued functions.
- Analytical properties of sequences.
- Infinite series, their properties and different tests.
- Limits, continuity, differentiability and mean value theorems.
- Fundamentals of numerical analysis, interpolation, numerical integration and difference equation.

UNIT I

Real Analysis: Representation of real numbers as points on the line and the set of real numbers as complete ordered field. Bounded and unbounded sets, neighborhoods and limit points, Supremum and infimum, derived sets, open and closed sets, sequences and their convergence, limits of some special sequences such as $r^n, \left(1+\frac{1}{n}\right)^n$ and $n^{\frac{1}{n}}$ and Cauchy's general principle of convergence, Cauchy's first theorem on limits, monotonic sequences, limit superior and limit inferior of a bounded sequence.

UNIT II

Infinite series, positive termed series and their convergence, Comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test, Raabe's test. Gauss test, Cauchy's condensation test and integral test (Statements and Examples only). Absolute convergence of series, Leibnitz's test for the convergence of alternating series, Conditional convergence.

UNIT III

Review of limit, continuity and differentiability, uniform Continuity and boundedness of a function. Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with Lagrange's and Cauchy's form of remainder (without proof). Taylor's and Maclaurin's series expansions of sinx, cosx, $e^x, (1+x)^n$, log (1+x).

UNIT IV

Numerical Analysis: Factorial, finite differences and interpolation. Operators, E and divided difference. Newton's forward, backward and divided differences interpolation formulae.

Lagrange's interpolation formulae. Central differences, Gauss and Stirling interpolation formulae. Numerical integration. Trapezoidal rule, Simpson's one-third rule, three-eights rule, Weddle's rule with error terms. Stirling's approximation to factorial n. Solution of difference equations of first order.

SUGGESTED READINGS:

1. Appostol, T.M. (1987). *Mathematical Analysis*, 2nd Ed., Narosa Publishing House, New Delhi.
2. Bartle, R.G. and Sherbert, D.R. (2002). *Introduction to Real Analysis*, (3rd Ed.,), John Wiley and Sons (Asia) Pte. Ltd., Singapore.
3. Ghorpade, S.R. and Limaye, B.V. (2006). *A Course in Calculus and Real Analysis,* Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint.
4. Jain, M.K., Iyengar, S.R.K. and Jain, R.K. (2003). *Numerical methods for scientific and engineering computation,* New age International Publisher, India.
5. Malik, S.C. and Arora, S. (1994). *Mathematical Analysis,* Second Edition, Wiley Eastern Limited, New Age International Limited, New Delhi.
6. Mukherjee, Kr. Kalyan (1990). *Numerical Analysis.* New Central Book Agency.
7. Sastry, S.S. (2000). *Introductory Methods of Numerical Analysis,* 3rd Ed., Prentice Hall of India Pvt. Ltd., New Delhi.
8. Narayan, S. (1987). *A course of Mathematical Analysis*, 12^{th} revised Ed., S. Chand & Co. (Pvt.) Ltd., New Delhi.
9. Somasundram, D. and Chaudhary, B. (1987). *A First Course in Mathematical Analysis*, Narosa Publishing House, New Delhi.

PRACTICAL/LAB WORK
List of Practicals:

1. Formation of difference table, fitting of polynomial and missing terms for equal interval of differencing.
2. Based on Newton's Gregory forward difference interpolation formula.
3. Based on Newton's backward difference interpolation formula.
4. Based on Newton's divided difference and Lagrange's interpolation formula.
5. Based on Gauss forward, Gauss backward central difference interpolation formula.
6. Based on Stirling's central difference interpolation formula.
7. Based on Lagrange's Inverse interpolation formula.
8. Based on method of successive approximation or iteration.
9. Based on method of reversion of series.
10. Based on Trapezoidal Rule, Simpson's one-third rule, Simpson's three-eighth rule, Weddle's rule.
11. To find sum by Euler-Maclaurin summation formula.

Week-wise Teaching Plan

Week 1	Real Analysis: Representation of real numbers as points on the line and the set of real numbers as complete ordered field. Bounded and unbounded sets, neighbourhoods and limit points, Supremum and infimum, derived sets, open and closed sets.
Week 2-3	Sequences and their convergence, limits of some special sequences such as $r^n, \left(1+\frac{1}{n}\right)^n$ and $n^{\frac{1}{n}}$ and Cauchy's general principle of convergence, Cauchy's first theorem on limits, monotonic sequences, limit superior and limit inferior of a bounded sequence.
Week 4-5	Series: Infinite series, positive termed series and their convergence, Comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test, Raabe's test. Gauss test, Cauchy's condensation test and integral test (Statements and Examples only).
Week 6	Absolute convergence of series, Leibnitz's test for the convergence of alternating series, Conditional convergence.
Week 7	Review of limit, continuity and differentiability, uniform Continuity and boundedness of a function.
Week 8-9	Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with Lagrange's and Cauchy's form of remainder (without proof). Taylor's and Maclaurin's series expansions of sinx, cosx, $e^x, (1+x)^n$, log (1+x).
Week 10-11	Numerical Analysis: Factorial, finite differences and interpolation. Operators, E and divided difference. Newton's forward, backward and divided differences interpolation formulae. Lagrange's interpolation formulae. Practical work
Week 12	Central differences, Gauss and Stirling interpolation formulae. Practical work
Week 13-14	Numerical integration. Trapezoidal rule, Simpson's one-third rule, three-eight rule, Weddle's rule with error terms. Stirling's approximation to factorial n. Practical work
Week 15	Solution of difference equations of first order. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Fundamental properties of real numbers and real-valued functions.	Class room lectures and discussions.	Participation in class and discussion.
I	Analytical properties of sequences.	Class room lectures and discussions.	Participation in class and discussion.
A*	Understanding of fundamentals and related properties of real numbers, real-valued functions and sequences.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts
II	About infinite series their properties and tests.	(i) Class room lectures and	Participation in class and

III	About limits, continuity, differentiability and Mean Value Theorems and their uses.	discussions. (ii) Practical work based on the numerical analysis.	discussion.
IV	Fundamentals of numerical analysis including interpolation, numerical integration and difference equation.		
B*	Understanding of infinite series, limits, continuity, finite differences, interpolation, numerical integration and difference equation.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.

* As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Real Analysis, Sequences and their convergence, Numerical Analysis, Central differences, Numerical integration, Solution of difference equations of first order.

Bachelor of Science (Hons.) in Statistics
Semester IV
STAT-C-401: Statistical Inference

Credit 6 **Marks:150**

Course Objectives:
The learning objectives include:
- Drawing inference about the unknown population parameters based on random samples.
- Validating our estimation/ inference about the population using hypothesis testing.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
1. Different methods of finding point estimators for unknown population parameters, their advantages and disadvantages:
   - Maximum Likelihood Estimation
   - Method of Moments
   - Method of Minimum Chi square and Modified Minimum Chi square
2. Desirable properties of point estimators based on which estimators can be compared:
   - Unbiasedness
   - Consistency
   - Efficiency
   - Sufficiency
3. Methods to develop/find best point estimators based on the desirable properties (Using Cramer- Rao inequality, Rao-Blackwell theorem, and Lehmann-Scheffe Theorem).
4. General methods of constructing interval estimators (Confidence Intervals) for unknown population parameters.
5. Basic principle of Bayesian estimation (Finding posterior distributions of unknown population parameters).
6. Developing/ constructing best/most powerful statistical tests to test hypotheses regarding unknown population parameters (Using Neyman-Pearson Lemma and Likelihood Ratio tests).
7. Practical applications of estimation theory and hypothesis testing pertaining to all discussed methods.

Contents:

UNIT I

Estimation: Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Fisher- Neyman Criterion (statement and applications), Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality, MVB estimators and their applications.

UNIT II

Methods of Estimation: Method of moments, method of maximum likelihood estimation, method of minimum Chi-square, basic idea of Bayes estimators.

UNIT III

Principles of test of significance: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU). Neyman Pearson Lemma and its applications to construct most powerful test. Likelihood ratio test, properties of likelihood ratio tests (without proof).

UNIT IV

Interval estimation: Confidence interval for the parameters of various distributions, Confidence interval for Binomial proportion, Confidence interval for population correlation coefficient for Bivariate Normal distribution, Pivotal quantity method of constructing confidence interval, Large sample confidence intervals.

SUGGESTED READINGS:

1. Bhat, B.R, Srivenkatramana, T. and Rao, Madhava K.S. (1997). *Statistics: A Beginner's Text*, Vol. I, New Age International (P) Ltd.
2. Dudewicz, E. J., and Mishra, S. N. (1988). *Modern Mathematical Statistics*. John Wiley & Sons.
3. Goon, A.M., Gupta, M.K.,and Dasgupta, B. (2005). *Fundamentals of Statistics*, Vol. I, World Press, Kolkata.
4. Miller, I. and Miller, M. (2002). *John E. Freund's Mathematical Statistics*, 6th Ed., Prentice Hall of India.
5. Mood A.M., Graybill F.A. and Boes D.C. (1974). *Introduction to the Theory of Statistics*, McGraw Hill.
6. Rohatgi, V. K. and Saleh, A.K. Md. E. (2009). *An Introduction to Probability and Statistics*. 2nd Ed., (Reprint) John Wiley and Sons.
7. Snedecor, G.W and Cochran, W.G. (1967). *Statistical Methods*. Iowa State University Press.

PRACTICAL/LABWORK
List of Practicals

1. Unbiased estimators (including unbiased but absurd estimators).
2. Consistent estimators, efficient estimators and relative efficiency of estimators.
3. Cramer-Rao inequality and MVB estimators.
4. Sufficient Estimators: Factorization Theorem, Rao-Blackwell theorem, CompleteSufficient estimators.
5. Lehman-Scheffe theorem and UMVUE.

6. Maximum Likelihood Estimation.
7. Asymptotic distribution of maximum likelihood estimators.
8. Estimation by the method of moments, minimum Chi-square.
9. Type I and Type II errors.
10. Most powerful critical region (NP Lemma).
11. Uniformly most powerful critical region.
12. Unbiased critical region.
13. Power curves.
14. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis.
15. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis.
16. Asymptotic properties of LR tests.

Week-wise Teaching Plan

Week 1-2	Concepts of estimation, unbiasedness, consistency. Including Practical work.
Week 3-4	Concepts of Efficiency. Minimum variance unbiased estimator (MVUE), Cramer-Rao inequality, MVB estimators and their applications. Including Practical work.
Week 5-7	Concepts of Sufficiency. Fisher-Neyman Criterion (statement and applications), Factorization theorem, completeness, Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Including Practical work.
Week 8-9	Methods of estimation: Method of Maximum Likelihood, Method of Moments, method of minimum Chi-square, basic idea of Bayes estimators. Including Practical work.
Week 10-11	Interval estimation - Confidence interval for the parameters of various distributions, Confidence interval for Binomial proportion, Confidence interval for population correlation coefficient for Bivariate Normal distribution, Pivotal quantity method of constructing confidence interval, Large sample confidence intervals. Including Practical work.
Week 12	Principles of test of significance: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power. Including Practical work.
Week 13-15	Best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU). Neyman Pearson Lemma and its applications to construct most powerful test. Likelihood ratio test, properties of likelihood ratio tests (without proof). Including Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Estimation: Concepts of estimation, and properties of estimators: unbiasedness,	(i) Class room lectures and discussions. (ii) Data based practical	(i) Participation in class discussion. (ii) To identify the best

	sufficiency, consistency and efficiency. Fisher-Neyman Criterion, Factorization theorem, Rao-Blackwell and Lehmann-Scheffe theorems, Cramer-Rao inequality.	applications of the theoretical concepts.	estimators relevant for given data/sample from real life situations (based on their properties).
II	Methods of Estimation: Method of moments, method of maximum likelihood estimation, method of minimum Chi-square, basic idea of Bayes estimators.	(i) Class room lectures and discussions. (ii) Data based practical applications of the theoretical concepts. (iii) Comparison of results based on different methods.	(i) Participation in class discussion. (ii) To assess the performance of methods of estimation under different real life situations.
I- II			Class test/assignment on first two units
III	Principles of test of significance: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power of the test.	(i) Class room lectures and discussions. (ii) Practical applications based on formulation of hypotheses, determination of size of critical regions and construction of power functions.	(i) Participation in class discussion. (ii) Ability to apply concepts in practical examples.
III	Best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU). Neyman Pearson Lemma. Likelihood ratio test.	(i) Class room lectures and discussions. (ii) Practical work.	(i) Participation in class discussion. (ii) Ability to construct best critical regions (tests) for both simple and composite hypotheses for given real life problems.
IV	Interval estimation - Confidence interval for the parameters of various distributions. Pivotal quantity method of constructing confidence interval. Large sample confidence intervals.	(i) Class room lectures and discussions. (ii) Practical work.	(i) Participation in class discussion. (ii) Ability to apply concepts in practical examples.
III-IV			Class test/assignment on last two units.

Keywords: Point estimation, Methods of estimation, Test of significance, Critical region, p value, Interval estimation, Confidence interval.

Bachelor of Science (Hons.) in Statistics
Semester IV
STAT-C-402: Linear Models

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include developing a clear understanding of the fundamental concepts of linear models and a range of associated skills allowing the students to work effectively with them.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance and Covariance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics, awareness of potential problems (outliers, etc.) and application of remedies to deal with them.

Contents:

UNIT I

Gauss-Markov set up: Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance. Distribution of quadratic forms.

UNIT II

Regression analysis: Simple Regression analysis, Estimation and hypothesis testing in case of simple and multiple regression analysis, Confidence intervals and Prediction intervals, Concept of model matrix and its use in estimation. Effect of orthogonal columns in the X matrix, Partial F-test and Sequential F-test, Bias in regression estimates.

UNIT III

Analysis of Variance and Covariance: Definition of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effect models, analysis of variance in two-way classified data with equal number of observations per cell for fixed effect models.

UNIT IV

Model checking: Prediction from a fitted model, Residuals and Outliers, Lack of fit and pure error, Violation of usual assumptions concerning normality, Homoscedasticity and collinearity, Diagnostics using quantile-quantile plots. Model Building: Techniques for Variable selection. Polynomial Regression models: Orthogonal Polynomials.

SUGGESTED READINGS:

1. Draper, N. R. and Smith, H. (1998): *Applied Regression Analysis*, 3rd Ed., John Wiley and Sons.
2. Montgomery, D. C., Peck, E. A. and Vining, G. G. (2004): *Introduction to Linear Regression Analysis*, 3rd Ed., John Wiley and Sons.
3. Rencher, A. C. and Schaalje, G. B. (2008): *Linear Models in Statistics*, 2nd Ed., John Wiley and Sons.
4. Weisberg, S. (2005): *Applied Linear Regression*, 3rd Ed., John Wiley and Sons.

PRACTICAL/LABWORK
List of Practicals

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Regression.
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Stepwise regression procedure.
10. Analysis of Variance of a one way classified data.
11. Analysis of Variance of a two way classified data with one observation per cell.
12. Analysis of Variance of a two way classified data with m (> 1) observations per cell.
13. Analysis of Covariance of a one way classified data.
14. Residual Analysis.
15. Orthogonal Polynomials.

Week-wise Teaching Plan:

Week 1	General Linear model-Definition, representations and classification.
Week 2-3	Estimability, Gauss Markov Theorem, Estimation of error variance Concepts of linear parametric functions, estimable functions, Conditions of estimability, Gauss Markov Theorem (for full rank and non-full rank cases) with proof, Concept of number of linearly independent functions. Practical work.
Week 4-5	Distribution of Quadratic forms; Cochran's Theorem and associated theorems with proof. Practical work.
Week 6-7	Regression Analysis-Simple Linear Regression model, Least squares estimation of the parameters, Testing of Hypotheses, Interval estimation, Prediction, Coefficient of Determination, Regression through the origin.

	Practical work.
Week 8-9	Multiple Linear Regression model, Estimation of model parameters, Testing of hypotheses-Global test, Test on Individual Regression Coefficients, Test for subset of Regression coefficients, Extra Sum of Squares method, Partial F test, Sequential test, Orthogonal columns of X matrix, Confidence Intervals. Practical work.
Week 10	Prediction from a fitted model. Practical work.
Week 10	Bias in regression estimates. Practical work.
Week 11	Analysis of Variance and Covariance-Definition of fixed, random and mixed effect models. Practical work.
Week 11-13	Analysis of Variance under Fixed effects model for one way classified data and two way classified data with equal number of observations per cell. Analysis of Covariance under fixed effects model for one way. Practical work.
Week 14	Selection of best linear regression equation by stepwise procedure. Practical work.
Week 14-15	Model Adequacy checking- Residuals and outliers, violation of assumption of Normality, Lack of fit and pure error. Practical work.
Week 15	Polynomial models: Orthogonal Polynomials. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Theory and estimation of Linear Models.	Class room lectures and discussions.	Participation in class discussion.
I	Gauss-Markov Theorem and its use.	(i) Class room lectures and discussions. (ii) Practical work based on the design and analysis.	(i) Participation in class discussions. (ii) Solution of real life problems using the concepts learnt.
I	Distribution of quadratic forms and Concept of number of linearly independent functions.		
II	Simple and Multiple linear regression models and their applications.		
II	Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.		
A*	Based on Units I and II.	Class Test/ Assignment Work.	Extent of clarity in theoretical concepts.
III	Techniques of Analysis of Variance and Covariance under fixed effects model.	(i) Class room lectures and discussions.	(i) Participation in class discussions. (ii) Solution of real life
IV	Assessment of the quality of the		

	fit using classical diagnostics, awareness of potential problems (outliers, influential observations, etc.) and application of remedies to deal with them.	(ii) Practical work based on the design and analysis.	problems using the concepts learnt.
B*	Based on Units III to IV.	Class Test/ Assignment Work.	Extent of clarity in theoretical concepts.
C	Application of Linear Models (optional).	Project work	Ability to apply concepts learnt under the course to real life problems. (Use secondary data only)

* As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Analysis of Variance and Covariance, Gauss-Markov Theorem, Regression Analysis, Lack of fit and pure error, Homoscedasticity and Collinearity, Orthogonal Polynomials.

Bachelor of Science (Hons.) in Statistics

Semester IV
STAT-C-403: Statistical Quality Control

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:

- This course will help students to learn techniques and approach of SQC being used in industry to manufacture goods and services of high quality at low cost.
- This course will also give exposure to Six sigma and Index Numbers.

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

- Statistical process control tools- Control charts for variables, attributes.
- Statistical product control tools- Sampling inspection plans.
- Overview of Six sigma- Lean manufacturing, TQM.
- Overview of Six sigma training plans, VOC, CTQ.
- Weighted and Unweighted Index Numbers.
- Base shifting, splicing and deflating of Index Numbers.

Contents:

UNIT I

Quality: Definition, dimensions of quality, its concept, application and importance. Introduction to Process and Product Controls. Statistical Process Control - Seven tools of SPC, chance and assignable Causes of quality variation. Introduction to Six-Sigma: Overview of Six Sigma, Lean Manufacturing and Total Quality Management (TQM). Organizational Structure and Six Sigma training plans- Selection Criteria for Six-Sigma roles and training plans. Voice of customers (VOC): Importance and VOC data collection. Critical to Quality (CTQ), Introduction to DMAIC.

UNIT II

Statistical Control Charts- Construction and Statistical basis of 3-σ Control charts, Control charts for variables: $\bar{X}$& R-chart, $\bar{X}$& s-chart. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Rational Sub-grouping. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart, estimation of process capability.

UNIT III

Acceptance sampling plan: Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.

UNIT IV

Index Numbers: Definition, construction of index numbers and problems thereof for weighted and unweighted index numbers including Laspeyre's, Paasche's, Edgeworth-Marshall and Fisher's. Chain index numbers, conversion of fixed based to chain based index numbers and vice-versa. Consumer price index numbers. Compilation of indices, base shifting, splicing and deflating of index numbers. Uses and limitations of index numbers.

SUGGESTED READINGS:

1. Ehrlich, H. B. (2002). *Transactional Six Sigma and Lean Servicing*, 2nd Ed., St. Lucie Press.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). *Fundamentals of Statistics*, Vol. I & II, 8th Ed., The World Press, Kolkata.
3. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand.
4. David, H. (1995). *ISO Quality Systems Handbook*, 2nd Ed., Butterworth Heinemann Publication.
5. Montogomery, D. C. (2009). *Introduction to Statistical Quality Control*, 6th Ed., Wiley India Pvt. Ltd.

PRACTICAL/LAB WORK
List of Practicals

Mode of Conducting Practical Examination: The Students should encouraged to perform practical problems on computers using whatsoever software/package far as possible.

1. Construction and interpretation of statistical control charts for
   a) $\bar{X}$& R-chart
   b) $\bar{X}$& s-chart
   c) np-chart
   d) p-chart
   e) c-chart
   f) u-chart
2. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.
3. Calculation of process capability and comparison of 3-sigma control limits with specification limits.
4. Calculate price and quantity index numbers using simple and weighted average of price relatives.
5. To Calculate the Chain Base Index numbers.
6. To Calculate the Consumer Price Index numbers.
7. Practical based on shifting of base, splicing and deflating of index numbers.

Week-wise Teaching Plan

Week- 1	Introduction to quality dimensions of quality, Its concept, application and importance.
Week -2	Process and product control, Seven tools of SPC, Chance and Assignable causes of quality variation.
Week 3-5	Statistical Control Charts- Statistical basis of 3-σ Control charts, Control charts for variables: $\bar{X}$& R-chart, $\bar{X}$& s-chart. Rational Sub-grouping, Revised and Modified Control Limits. Practical work.
Week 5-7	Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart, estimation of process capability. Practical work.
Week 7-9	Acceptance sampling plan: Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables. Practical work.
Week 10	Introduction to Six-Sigma: Overview of Six Sigma, Lean Manufacturing and Total Quality Management (TQM).
Week 10	Organizational Structure and Six Sigma training plans.
Week 11-12	Overview of Selection Criteria for Six-Sigma roles and training plans. Voice of customers (VOC). Critical to Quality (CTQ). Introduction to DMAIC.
Week 12-13	Index Numbers: Definition, construction of index numbers and problems thereof for weighted and unweighted index numbers including Laspeyre's, Paasche's, Edgeworth-Marshall and Fisher's. Average of Price Relatives. Practical work.
Week 13-14	Chain index numbers, conversion of fixed based to chain based index numbers and vice-versa. Criteria of Good Index Numbers. Consumer price index numbers. Practical work.
Week 15	Base shifting, splicing and deflating of index numbers. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Introduction to Quality. Statistical process control tools, causes of variation. Overview of Six sigma- Lean manufacturing, TQM Six sigma training plans, VOC, CTQ. Introduction of DMAIC.	(i) Class room lectures and discussions.	Participation in class discussion.
II	Statistical process control tools- Control charts for variables, attributes.	(i) Class room lectures and discussions.	Participation in class discussion. Problem solving, Analyse and

		(ii) Practical problems from the list of practical.	Interpret the results.
A*	Understanding basic concepts and control charts.	Class Test/ Assignment work	Extent of clarity of theoretical concepts studied in the course.
III	Statistical product control tools- Sampling inspection plans, Dodge and Romig plans.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
IV	Construction of index numbers and problems thereof for weighted and unweighted index numbers. Criteria of Good Index Numbers. Base shifting, splicing and deflating of index numbers.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
B*	Understanding of complete course.	Class Test/ Assignment work	Extent of clarity of theoretical concepts studied in the course.
C	Application of statistical quality control. (optional)	Project Work and its presentation.	Ability to apply concepts of quality control, practical handling, understanding and giving solutions to a problem.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Statistical process/product control, Process capability, Control charts, Three sigma and specification limits, Single and Double sampling plans, Index number construction.

Bachelor of Science (Hons.) in Statistics
Semester V
STAT-C-501: Stochastic Processes and Queuing Theory

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To define, design and model;
- To analyze;
- To identify the real life applications of stochastic processes.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Stability of Markov chains.
- Poisson process and its variations.
- Queuing systems.
- Random walk and ruin theory.

Contents:

UNIT I

Probability Distributions: Generating functions, Bivariate probability generating functions. Stochastic Process: Introduction, Stationary Process.

UNIT II

Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains, stability of Markov system.

UNIT III

Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process, pure death process.

UNIT IV

Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof). Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

SUGGESTED READINGS:

1. Basu, A.K. (2005). *Introduction to Stochastic Processes*, Narosa Publishing.

2. Bhat,B.R. (2000). *Stochastic Models: Analysis and Applications*, New Age International Publishers.
3. Feller, W. (1968). *Introduction to probability Theory and Its Applications*, Vol I, 3rd Ed., Wiley International.
4. Medhi, J. (2009). *Stochastic Processes*, New Age International Publishers.
5. Taha, H. (1995). *Operations Research: An Introduction*, Prentice- Hall India.

PRACTICAL/LAB WORK
List of Practicals:

Mode of Conducting Practical Examination: The students should be encouraged to perform practical problems on computers using whatsoever software/package as far as possible.

1. Applications of Partial Fraction Theorem.
2. Problems based on (covariance) stationary processes.
3. Markov Chains:
   a) Simulation of Markov chains and Calculation of transition probability matrices.
   b) Stability of Markov chains.
   c) To check whether the given chain is irreducible or not.
   d) Computation of probabilities in case of generalizations of independent Bernoulli trials.
4. Simulation and applications of Poisson processes.
5. Calculation of probabilities for given birth and death processes.
6. Calculation of probabilities for ruin problems.
7. Problems based on (M/M/1) queuing models.

Week-wise Teaching Plan

Week 1-2	Probability Distributions: Generating functions, Bivariate probability generating functions.
Week 3-4	Stochastic Process: Introduction, Stationary Process.
Week 5-6	Markov Chains: Definition of Markov Chain with examples, transition probability matrix, order of Markov chain, Markov chain as graphs.
Week 7-8	Higher transition probabilities. Generalization of independent Bernoulli trials, classification of states and chains, Stability of Markov system.
Week 9-11	Poisson Process: postulates of Poisson process, properties of Poisson process, inter-arrival time, Pure birth process, Yule Furry process, birth and death process, pure death process.
Week 12-13	Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).
Week 14-15	Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Determination of $\{p_k\}$ from a given generating function (an application of partial fraction theorem).	(i) Class room lectures and discussions. (ii) Practical work	Participation in class discussion.
I	Generating function of sum of a random number of discrete random variables.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
I	The fundamental concepts of stochastic processes.	Class room lectures and discussions.	Participation in class discussion.
I	Tools needed to analyze stochastic processes.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Markov chains with examples.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Higher transition probabilities.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Classification of states and chains.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Reducible and irreducible Markov chains.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Stability of Markov chains.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
			Class test/assignment on first two units
III	Poisson process: postulates and Properties.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
III	Birth and death processes as application of Poisson process.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
III	Expected population size and its	(i) Class room	Participation in class

	variance under linear growth,birth and death process.	lectures and discussions. (ii) Practical work.	discussion.
IV	Queuing systems.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
IV	Random walk and ruin theory.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
			Class test/assignment on last two units.

Keywords: Probability Distributions, Markov Chain, Poisson process, Random walk, Queuing systems, Ruin Problem.

Bachelor of Science (Hons.) in Statistics

Semester V
STAT-C-502: Statistical Computing Using C/C++ Programming

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To understand computer programming and its roles in problem solving.
- To understand basic data structures and develop logics which will help them to create well-structured programs using C language.
- Learning the basic programming language will help students to easily switch over to any other language in future.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- Various data types, operators, library functions, Input/Output operations.
- Decision making and branching and looping.
- Arrays, Character and strings.
- User- defined functions, recursion functions.
- Storage class of Variables.
- Pointers.
- Pointers and arrays, arrays of pointers, pointers as function arguments, functions returning pointers.
- Structure, array of structures, structure pointers.
- Dynamic memory allocation functions.
- Pre-processors: Macro substitution, macro with argument.
- File inclusion in C/C++, I/O operations on files.

Contents:

UNIT I

History and importance of C/C++. Components, basic structure programming, character set, C/C++ tokens, Keywords and Identifiers and execution of a C/C++ program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data.Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement, operators, precedence of operators in arithmetic, relational and logical expression. Implicit and explicit type conversions in expressions, library functions. Managing input and output operations: reading and printing formatted and unformatted data.

UNIT II

Decision making and branching - if…else, nesting of if…else, else if ladder, switch, conditional (?) operator. Looping in C/C++: for, nested for, while, do…while, jumps in and out of loops. Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only).

UNIT III

User- defined functions: A multi -function program using user-defined functions, definition of functions, return values and their types, function prototypes and calls. Category of Functions : no arguments and no return values, arguments but no return values , arguments with return values, no arguments but returns a value, functions that return multiple values. Recursion function. Passing arrays to functions, Storage class of Variables.

UNIT IV

Pointers: Declaration and initialization of pointer variables, accessing the address of a variable, accessing a variable through its pointer, pointer expressions, pointer increments/decrement and scale factor. Pointers and arrays, arrays of pointers, pointers as function arguments, functions returning pointers Structure: Definition and declaring, initialization, accessing structure members, copying and comparison of structure variables, array of structures, structure pointers. Dynamic memory allocation functions: malloc, calloc and free. Pre-processors: Macro substitution, macro with argument File inclusion in C/C++: Defining and opening a file (only r, w and a modes), closing a file, I/O operations on files-fscanf and fprintf functions.

SUGGESTED READINGS:

1. Balagurusamy, E. (2011). *Programming in ANSI C*, Ed., and Tata McGraw Hill.
2. Gottfried, B.S. (1998). *Schaum's Outlines: Programming with C,* 2nd Ed., Tata McGraw Hill
3. Kernighan, B.W. and Ritchie, D. (1988). *C Programming Language*, 2nd Ed., Prentice Hall.

PRACTICAL/ LAB WORK

List of Practicals:

1. Plot of a graph y = f(x).
2. Roots of a quadratic equation (with imaginary roots also).
3. Sorting of an array and hence finding median.
4. Mean Median and Mode of a Grouped Frequency Data.
5. Variance and coefficient of variation of a Grouped Frequency Data.
6. Preparing a frequency table.
7. Value of n! using recursion.
8. Random number generation from uniform, exponential, normal (using CLT) and gamma distribution calculate sample mean and variance and compare with population parameters.
9. Matrix addition, subtraction, multiplication Transpose and Trace.

10. Fitting of Binomial, Poisson distribution and apply Chi-square test for goodness of fit.
11. Chi-square contingency table.
12. t-test for difference of means.
13. Paired t-test.
14. F-ratio test.
15. Multiple and Partial correlation.
16. Compute ranks and then calculate rank correlation (without tied ranks).
17. Fitting of lines of regression.

Week-wise Teaching Plan

Week 1-2	Overview of C, Constants, Variables and Data Types.
Week 2-3	Operators and Expressions.
Week 4	Managing Input and Output Operations.
Week 5-6	Decision Making and Branching, Develop programs to do statistical computing.
Week 6-7	Decision Making and Looping, Develop programs to do statistical computing.
Week 8-9	Arrays, Develop programs to do statistical computing related to arrays, matrices etc.
Week 10	Character Arrays, Strings.
Week 11	File Management in C, Develop programs to do statistical computing using files input/output files.
Week 11-13	User- defined Functions, Develop programs to do statistical computing using user defined functions, recursion.
Week13-14	Structure and Pointers, Develop programs to do statistical computing with the concept of structures and pointers.
Week 15	Dynamic Memory Allocation and the Preprocessor.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Various data types, operators, library functions, Input/ Output operations.	(i) Class room lectures and discussions. (ii) Solving of arithmetic expressions involving all types of operators.	Participation in class discussion. Understanding the logic of expression solving hierarchy.
II	Decision making and branching and looping.	(i) Class room lectures and discussions. (ii) Writing of small program segments and solving exercise	Participation in class discussion.

		questions from suggested readings.	Understanding the logic of expression solving hierarchy with decision making and loops.
II	Arrays, Character and strings.	(i) Class room lectures and discussions. (ii) Writing full statistical computing programs mentioned in the list of practical and running on Computer with data.	Participation in class discussion. Ability to write full program with a dry run and error free program on computer.
A*	Understanding basic concepts and writing of programs using arrays.	Class Test/ Assignment work.	Extent of clarity of theoretical concepts studied in the course.
III	User- defined functions, recursion functions. Storage class of Variables.	(i) Class room lectures and discussions. (ii) Writing full statistical computing programs mentioned in the list of practical and running on Computer with data.	(i) Participation in class discussion. (ii) Ability to write full program with a dry run and error free program on computer.
IV	Pointers.	(i) Class room lectures and discussions. (ii) Writing of small program segments and solving exercise questions from suggested readings.	Participation in class discussion. Understanding the concept of pointers.
IV	Pointers and arrays, arrays of pointers, pointers as function arguments, functions returning pointers.	(i) Class room lectures and discussions. (ii) Writing full statistical computing programs mentioned in the list of practical and running on Computer with data.	(i) Participation in class discussion. (ii) Ability to write program pointers with a dry run and error free program on computer.
IV	Structure, array of structures, structure pointers. Dynamic memory allocation functions.	(i) Class room lectures and discussions. (ii) Writing of small program segments and solving exercise questions from suggested readings.	(i) Participation in class discussion. (ii) Understanding the concept of pointers in relation to structures and memory allocation.

IV	Pre-processors: Macro substitution, macro with argument. File inclusion in C/C++, I/O operations on files.	(i) Class room lectures and discussions. (ii) Writing of small program segments and solving exercise questions from suggested readings.	(i) Participation in class discussion. (ii) Ability to write C programs using files and run on computer.
B*	Understanding basic concepts and writing of programs using arrays, user-defined functions, pointers etc.	Class Test/ Assignment work.	Extent of clarity of theoretical concepts studied in the course.
C*	Ability to write and run complete error free program on computer.	Practical test on computers.	Practical handling of running understanding and rectifying errors in the program.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: C programming, Data types, Loops, Header files, Pre-processor directives, storage classes, Macros, Functions and arguments arrays, Pointers, Dynamic memory allocation.

Bachelor of Science (Hons.) in Statistics
Semester VI
STAT-C-601: Design of Experiments

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To design and conduct experiments.
- To analyze and interpret data.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- The fundamental concepts of design of experiments.
- Introduction to planning valid and economical experiments within given resources.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two and three levels.
- Fractional factorial designs with two levels.

Contents:

UNIT I

Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) -layout, model and statistical analysis, relative efficiency, analysis with missing observations.

UNIT II

Incomplete Block Designs: Balanced Incomplete Block Design (BIBD)-parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD, Intra Block analysis, complimentary BIBD, Residual BIBD, Dual BIBD, Derived BIBD.

UNIT III

Factorial experiments: Concepts, notations and advantages, 2^2, $2^3 \ldots 2^n$ and 3^2 factorial experiments, design and analysis, Total and Partial confounding for 2^n ($n \leq 5$), 3^2 and 3^3.Factorial experiments in a single replicate.

UNIT IV

Fractional factorial experiments: Construction of one-half and one-quarter fractions of 2^n ($n \leq 5$) factorial experiments, Alias structure, Resolution of a design.

SUGGESTED READINGS:

1. Cochran, W.G. and Cox, G.M. (1959). *Experimental Design*. AsiaPublishing House.

2. Das., M.N. and Giri, N.C. (1986). *Design and Analysis of Experiments*. Wiley Eastern

3. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). *Fundamentals of Statistics*. Vol. II, 8thEd. World Press, Kolkata.

4. Kempthorne, O. (1965). *The Design and Analysis of Experiments*. John Wiley.

5. Montgomery, D. C. (2008). *Design and Analysis of Experiments*. John Wiley.

PRACTICAL/LAB WORK
List of Practicals:

1. Analysis of a CRD with equal and unequal replicates.
2. Analysis of RBD.
3. Analysis of LSD.
4. Analysis of RBD with one missing observation.
5. Analysis of LSD with one missing observation.
6. Intra block analysis of BIBD.
7. Intra block analysis of a symmetric BIBD.
8. Analysis of 2^2 and 2^3 factorial in CRD, RBD and LSD.
9. Analysis of a 3^2 factorial in CRD and RBD.
10. Analysis of a completely confounded two level factorial design in 2 blocks.
11. Analysis of a completely confounded two level factorial design in 4 blocks.
12. Analysis of a partially confounded two level factorial design.
13. Analysis of a single replicate of a 2^n design.
14. Analysis of one half fraction of 2^n factorial design.
15. Analysis of one quarter fraction of 2^n factorial design.

Week-wise Teaching Plan

Week 1	Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks.
Week 2-3	Basic Designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD)-layout, model, statistical analysis, advantages and their applications. Practical work.
Week 3	Relative efficiencies of RBD compared to CRD, LSD compared to CRD, LSD compared to RBD taking rows as blocks, LSD compared to RBD taking columns as blocks. Practical work.
Week 4	Missing Plot technique (for both RBD and LSD) for one missing observation only, Variance of the difference between two estimated treatment effects out of which one has the missing observation (for both RBD and LSD). Practical work.
Week 5	Balanced Incomplete Block Design (BIBD): parameters, relationships among its parameters, incidence matrix and its properties.
Week 5	Intra Block analysis, Variance of the difference between two estimated treatment effects, Relative efficiency of BIBD compared to RBD. Practical

	work.
Week 6	Definition and Properties of Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD. Practical work.
Week 7	Construction of complimentary BIBD, Residual BIBD, Dual BIBD, Derived BIBD.
Week 8	Factorial Experiments: Advantages over simple experiments, notations, concepts of main effects and interaction effects.
Week 9	2^n Factorial Designs -Standard order for treatment combinations, Main effects and interactions, Yates' Algorithm, Design and analysis. Practical work.
Week 10	3^n Factorial Designs - Standard order for treatment combinations, Main effects and interactions, Yates' Algorithm, Design and analysis (n=2).Practical work.
Week 11-13	Total and Partial confounding- Confounding 2^n ($n \leq 5$) in two blocks and four blocks, Confounding the 3^n ($n \leq 3$) in three blocks, identification of the confounded effects for both 2^n ($n \leq 5$) and 3^n ($n \leq 3$) factorial designs. Practical work.
Week 13	Analysis of a single replicate. Practical work.
Week 14	Fractional Factorial Designs: Introduction, Concepts - Word, Defining Relation, Principal and Complementary Fractions, Aliases, Alias Structure, Resolution of a Design, Construction of Resolution III, IV and V Designs.
Week 15	Construction of one half and one-quarter fractions of 2^n ($n \leq 5$). Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	The fundamental concepts of design of experiments.	Class room lectures and discussions.	Participation in class discussion.
I	Introduction to planning valid and economical experiments within given resources.	Class room lectures and discussions.	Participation in class discussion.
I	Completely randomized designs.	(i) Class room lectures and discussions. (ii) Practical work based on the design and analysis.	(i) Participation in class discussion. (ii) Identification of design, model, formulation of null hypothesis, appropriate analysis, interpretation of results and conclusion.
I	Randomized block design.		
I	Latin square design.		
A*	Understanding of fundamentals and design and analysis of basic	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.

	designs.		
II	Balanced incomplete block design.	(i) Class room lectures and discussions. (ii) Practical work based on the design and analysis.	(i) Participation in class discussion. (ii) Identification of design, model, formulation of null hypothesis, appropriate analysis, interpretation of results and conclusion.
III	Full and confounded factorial designs with two and three levels.		
IV	Fractional factorial designs with two levels.		
B*	Understanding of BIBD, Full and confounded factorial and Fractional factorial designs.	Class Test/ Assignment work	Extent of clarity in theoretical concepts.
C	Application of design of experiments. (optional)	Project work and its presentation.	Ability to apply concepts of designing and analysing experiments.

* As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Design of experiments, Completely randomized designs, Latin square design, Balanced incomplete block design, Fractional experiments, Fractional factorial experiments, confounding, Resolution of design.

Bachelor of Science (Hons.) in Statistics

Semester VI

STAT-C-602: Multivariate Analysis and Non-Parametric Methods

Credits:6 **Marks:150**

Course Objectives:

The learning objectives include:

- Study of theoretical concepts of Bivariate Normal and Multivariate Normal Distributions along with their properties.
- Analyze multivariate data.
- Application of Wald's SPRT and Non-Parametric methods of testing of hypothesis.

Course Learning Outcomes:

On completion of the course, students should have achieved the following:

- The understanding of basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- Analyzing Multivariate data using data reduction techniques like Principal Component Analysis, Factor Analysis.
- Classification method namely Discriminant Analysis.
- Application of Wald's SPRT for testing simple null hypothesisvs simple alternative hypothesis along with the study of the O.C. function and the ASN function for various underlying continuous and discrete distributions.
- Testing of hypothesis using Non-Parametric tests like Median test, Runs test, U test, Kruskal Wallis test etc. and ability to use them judiciously for the testing of given data.

Contents:

UNIT I

Bivariate Normal Distribution (BVN): pdf of BVN, properties of BVN, marginal and Conditional pdf of BVN. Multivariate Data: Random Vector: Probability mass/density functions, Distribution Function, Mean vector, Dispersion matrix, Marginal distributions, Conditional distributions.

UNIT II

Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance-covariance matrix. Multiple and partial correlation coefficient and their properties. Introduction to discriminant Analysis, Principal Components Analysis and Factor Analysis.

UNIT III

Sequential Analysis: Sequential probability ratio test (SPRT) for simple v/s simple Hypotheses. Fundamental relations among α, β, A and B, determination of A and B in Practice. Wald's fundamental identity and the derivation of operating characteristics (OC)

and average sample number (ASN) functions, examples based on normal, Poisson, binomial and exponential distributions.

UNIT IV

Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, Kolmogorov Smirnov test for one sample, Sign tests- one sample and two samples, Wilcoxon-Mann-Whitney test, Kruskal-Wallis test.

SUGGESTED READINGS:

1. Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, 3rd Ed., John Wiley& Sons.
2. Arora, S.and Bansi, L. (1968). *New Mathematical Statistics*, 1st Ed., Vanita Printers.
3. Gibbons, J. D. and Chakraborty, S. (2003). *Non-Parametric Statistical Inference*. 4thEd., Marcel Dekker, CRC.
4. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005). *An Outline of Statistical Theory*, Volume II, World Press.
5. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand.
6. Johnson, R.A. and Wichern, D.W. (2007). *Applied Multivariate Analysis*, 6th Ed., Prentice Hall.
7. Kshirsagar, A.M. (1972). *Multivariate Analysis*, 1st Ed., Marcel Dekker.
8. Muirhead, R.J. (1982). *Aspects of Multivariate Statistical Theory*, John Wiley.
9. Mukhopadhyay, P. (2015). *Mathematical Statistics.*
10. Rao, C. R. (2000). *Linear Statistical Inference,* John Wiley & Sons.
11. Siegel, S. and Castellan, N.J. (1988). *Non-Parametric Statistics for the Behavioral Sciences*, 2nd Ed., International Edition.
12. Siegel, S. (1956). *Non-Parametric Statistics for the Behavioral Sciences*, McGraw Hill.

PRACTICAL/LAB WORK

List of Practicals:

1. Bivariate Normal Distribution and it's properties.
2. Multivariate Normal Distribution and it's properties.
3. Partial Correlation Coefficient.
4. Multiple Correlation Coefficient.
5. Plane of Regression.
6. Principal Component Analysis.
7. Discriminant analysis.
8. Factor Analysis.
9. SPRT Procedure and Graphical representation of decision lines, acceptance and rejection regions.

10. ASN function and ASN curve.
11. OC function and OC curve.
12. Test for randomness based on total number of runs.
13. Kolmogorov Smirnov test for one sample.
14. Sign test: one sample, two sample, large samples.
15. Wilcoxon-Mann-Whitney U – test.
16. Kruskal - Wallis test.
17. Wald- Wolfowitz test.
18. Median Test.

Week-wise Teaching Plan

Week 1	Basic Concepts: random vector, pdf, mean vector, dispersion matrix, distribution function, marginal and conditional distribution of random vector.
Week 2-3	Bivariate Normal Distribution (BVN), Marginal and Conditional Distribution of BVN, mgf of BVN. Practical work.
Week 4-6	Multivariate Normal Distribution (MVN), Marginal and Conditional Distribution of MVN, mgf of MVN, Statistical Independence, Distribution of linear combination of normally distributed variates, Characteristic function, Practical work.
Week 7	Sampling Distribution of X and S.
Week 8	Multiple and Partial Correlation Coefficient and Plane of Regression. Practical work.
Week 9-11	Data Reduction and Classification Techniques: Principal Component Analysis, Factor Analysis, Discriminant Analysis. Practical work.
Week 12-13	SPRT for simple vs. Simple hypotheses, Relations among α, β, A and B. Determination of A and B in practice, Wald's Identity, ASN and OC functions with examples based on Normal (for Mean when Variance specified and for Variance when Mean specified), Exponential, Binomial and Poisson distributions. Practical work.
Week 14-15	Nominal, Ordinal Interval, Ratio scales of measurement, Advantages and disadvantages of non- parametric tests vis a vi Parametric tests, Theory and application of Non-Parametric Tests: - Kolmogorov-Smirnov one sample test, One sample run test for randomness, Sign test, Median Test, Mann-Whitney U test, Wald Wolfowitz Run test, Kruskal Wallis test. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Function, marginal and conditional The fundamental concepts related to random variable, mean vector, dispersion matrix, and	Class room lectures and discussions.	Participation in class discussion.

	characteristic distributions.		
I	Bivariate Normal Distribution and its Properties.	(i) Class room lectures and discussions. (ii) Practical work based on properties of BVN.	(i) Participation in class discussion. (ii) Doing assignments comprising of problems based on BVN.
II	Multivariate Normal Distribution and its Properties.	(i) Class room lectures and discussions. (ii) Practical work based on properties of MVN.	(i) Participation in class discussion. (ii) Doing assignments comprising of problem based on MVN.
II	Sampling Distribution of $\bar{X}$ and S.	Class room lectures and discussions.	Participation in class discussion.
II	Multiple and Partial Correlation Coefficient and Plane of Regression.	(i) Class room lectures and discussions. (ii) Practical work based on computation and interpretation of multiple and partial correlation coefficients for more than 3 variables, obtaining equations of planes of regression and use them for prediction.	Participation in class discussion.
A*	Understanding of fundamentals and properties of BVN and MVN, multiple and partial correlation coefficients with related problems.	Class Test/ Assignment work.	Extent of clarity in Theoretical concepts and their applications.
III	Wald's SPRT procedure for simple vs. simple hypotheses, ASN and OC functions.	Class room lectures and discussions. Practical work based on: - Construction of SPRT for testing the hypotheses, ASN and OC functions and their graphical representations.	(i) Participation in class discussion. (ii) Doing assignments comprising of problems based on SPRT, ASN and OC functions for Normal, Binomial, Poisson and Exponential
IV	Nominal, Ordinal, Interval and Ratio scales of measurement.	Class room lectures and discussions.	Participation in class discussion.
IV	Knowledge and Understanding of Non-Parametric tests.	(i) Class room lectures and discussions. (ii)Practical work based on formulation of hypotheses,	(i) Participation in class discussion. (ii) Doing assignments comprising of

		application of an appropriate NP test and interpretation of results.	problems based on application of NP tests to the real-life data.
B*	Understanding of SPRT, OC and ASN function, Non-Parametric tests.	Class Test/ Assignment Work.	Extent of clarity in theoretical concepts and their applications.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Bivariate Normal Distribution, Multivariate Normal Distribution, Principal Components Analysis and Factor Analysis, Discriminant Analysis, Sequential probability ratio test, Operating characteristics (OC), Average sample number (ASN) functions, Non-Parametric tests.

DSE Papers in Statistics

Bachelor of Science (Hons.) in Statistics
Semester-V
STAT-DSE – 1 (A): Time Series Analysis

Credit –6 **Marks: 150**

Course Objectives:
The course objectives include:
- Understanding of the process generating a time series.
- Forecasting future values of the observed series.

Course Learning Outcomes:
After completing this course, the students will possess skills to understand the components and forecast values of a time series at future time points.

Contents:

UNIT I

Introduction to times series data, application of time series from various fields, Components of a times series, Decomposition of time series. Estimation of trend by free hand curve method, method of semi averages, fitting mathematical curve and growth curves. Estimation of trend by method of moving averages. Detrending: effect of elimination of trend on other components of a time series.

UNIT II

Seasonal Component: Estimation of seasonal component by the methods of - simple averages, Ratio to Trend, Ratio to Moving Averages and Link Relative method. Deseasonalization. Cyclic Component: Harmonic Analysis.

UNIT III

Random Component: Variate difference method. Stationary Time series: Weak stationarity, autocorrelation function and the correlogram. Some Special Processes: Moving-average (MA) process and Autoregressive (AR) processes. Estimation of the parameters of AR (1) and AR (2). Autocorrelation functions of AR(1) and AR(2) processes.

UNIT IV

Introduction to methods of Forecasting a time series. Forecasting by the methods of Exponential smoothing. Introduction to ARMA and ARIMA models. Short-term forecasting methods Brown's discounted regression, Box-Jenkins method and Bayesian forecasting.

SUGGESTED READINGS:

1. Kendall, M.G. (1976*). Time Series*, 2nd Ed., Charles Griffin and Co Ltd., London and High Wycombe.
2. Chatfield, C. (1980). *The Analysis of Time Series –An Introduction*, Chapman & Hall.

3. Mukhopadhyay, P. (2011). *Applied Statistics*, 2nd Ed., Revised reprint, Books and Allied
4. Goon, A. M., Gupta, M. K. and Dasgupta, B. (2003). *Fundamentals of Statistics*, 6th Ed., Vol II Revised,Enlarged.
5. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand and Sons.
6. Montgomery, D. C. and Johnson, L. A. (1967). *Forecasting and Time Series Analysis*, 1st Ed. McGraw-Hill, New York.

PRACTICAL / LAB WORK
List of Practicals:

1. Fitting and plotting of modified exponential curve by different methods.
2. Fitting and plotting of Gompertz curve by different methods.
3. Fitting and plotting of logistic curve by different methods.
4. Fitting of trend by Moving Average Method for given extent and for estimated extent.
5. Fitting of trend by Spencer's 15-point and 21-point formulae.
6. Measurement of Seasonal indices:
   a) Simple Averages method
   b) Ratio-to-Trend method
   c) Ratio-to-Moving Average method
   d) Link Relative method
7. Estimation of variance of the random component by variate difference method.
8. Forecasting by exponential smoothing.
9. Plotting of Correlogram of moving average.

(May be done using EXCEL, SPSS, R, Calculators)

Week-Wise Teaching Plan

Week 1	Introduction to times series data, application of time series from various fields, Components of a times series, Decomposition of time series.
Week 2-3	Estimation of trend by free hand curve method, method of semi averages, fitting mathematical curve and growth curves. Practical work.
Week 3-4	Estimation of trend by method of moving averages. Detrending: Effect of elimination of trend on other components of a time series. Practical work.
Week 5-7	Seasonal Component: Estimation of seasonal component by the methods of: Simple averages, Ratio to Trend, Ratio to Moving Averages and Link Relative method. Deseasonalization. Practical work.
Week 8-9	Cyclic Component: Harmonic Analysis. Random Component: Variate difference method. Practical work.
Week 9-11	Stationary Time series: Weak stationarity, autocorrelation function and the correlogram. Some Special Processes: Moving-average (MA) process and Autoregressive (AR) processes. Estimation of the parameters of AR (1) and AR (2). Autocorrelation functions of AR(1) and AR(2) processes. Practical work.
Week 11-12	Introduction to methods of Forecasting a time series. Forecasting by the

	methods of Exponential smoothing. Practical work.
Week 12	Introduction to ARMA and ARIMA models.
Week 13	Short-term forecasting method: Brown's discounted regression.
Week 14	Short-term forecasting method: Box-Jenkins method.
Week 15	Short-term forecasting method: Bayesian forecasting.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Concept and application of time series.	Class room lectures, presentations and discussions.	Participation in class discussion.
I	Components and decomposition of time series.	Class room lectures and discussions.	Participation in class discussion.
I	Trend component.	(i)Class room lectures and discussions. (ii) Practical work.	(i) Participation in class discussion. (ii) Appraisal of different components.
II	Seasonal component.		
II	Cyclical component.		
III	Random component		
A*	Understanding of basic concept of time series and its components.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
III	Stationary time series.	(i) Class room lectures and discussions. (ii) Practical work.	(i) Participation in class discussion. (ii) Appraisal of different forecasting methods.
III	Some special processes.		
IV	Introduction to methods of forecasting a times series.		
	Forecasting by methods of exponential smoothing.		
	Short term forecasting.		
B*	Understanding of stationary time series, special processes and forecasting methods.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Component and Decomposition of time series, Autocorrelation function and the correlogram, Moving-average (MA) process and Autoregressive (AR) processes, forecasting a time

Bachelor of Science (Hons.) in Statistics
Semester V
STAT-DSE-1(B): Demography and Vital Statistics

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To collect valid Demographic data using different methods.
- To learn basic measures of Mortality, Fertility and Population Growth.
- To construct life tables.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- Distinction between Vital Statistics and Demography.
- Errors in Demographic data.
- To check the completeness of registration data using Chandrasekaran-Deming formula.
- Use of Myer's and UN indices in evaluating age data.
- Use of Balancing Equations.
- Population Composition and Dependency Ratio.
- Sources of data collection on Vital Statistics and errors therein.
- Measurement of Population.
- Distinction between Rate and Ratio.
- Basic measures of Mortality.
- Concepts of Stable and Stationary Populations.
- Concept of Life Tables, their construction and uses.
- Concept of Abridged life tables and their construction by Reed and Merrell method, Greville's method and King's Method.
- Basic measures of Fertility.
- Measures of Population Growth.

Contents:

UNIT I

Population Theories: Coverage and content errors in demographic data, use of balancing equations and Chandrasekaran-Deming formula to check completeness of registration data. Adjustment of age data, use of Myer and UN indices, Population composition, dependency ratio.

UNIT II

Introduction and sources of collecting data on vital statistics, errors in census and registration data. Measurement of population, rate and ratio of vital events. Measurements of Mortality: Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates.

UNIT III

Stationary and Stable population, Central Mortality Rates and Force of Mortality. Life(Mortality) Tables: Assumption, description, construction of Life Tables and Uses of Life Tables.

UNIT IV

Abridged Life Tables; Concept and construction of abridged life tables by Reed-Merrell method, Greville's method and King's Method. Measurements of Fertility: Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR) and Total Fertility Rate (TFR). Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR).

SUGGESTED READINGS:

1. Biswas, S. (1988). *Stochastic Processes in Demography & Application*, Wiley Eastern Ltd.
2. Croxton, Fredrick, E. Cowden, Dudley J. and Klein, S. (1973). *Applied General Statistics*, 3rd Ed., Prentice Hall of India Pvt. Ltd.
3. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008). *Fundamentals of Statistics*, Vol. II, 9thEd., World Press.
4. Keyfitz, N. and Beekman,J.A. (1985). *Demography through Problems*. S-Verlag, New York.
5. Mukhopadhyay, P. (1999). *Applied Statistics*, Books and Allied (P) Ltd.

PRACTICAL/LAB WORK
List of Practicals:

1. To calculate CDR and Age Specific death rate for a given set of data.
2. To find standardized death rate by: (i) Direct method (ii) Indirect method.
3. To construct a complete life table.
4. To fill in the missing entries in a life table.
5. To calculate probabilities of death at pivotal ages and use it construct abridged life table using: (i) Reed-Merrell Method, (ii) Greville's Method and (iii) King's Method.
6. To calculate CBR, GFR, SFR, TFR for a given set of data.
7. To calculate Crude rate of Natural Increase and Pearle's Vital Index for a given set of data.
8. Calculate GRR and NRR for a given set of data and compare them.

Week-wise Teaching Plan

Week 1	Meaning of Demography and Population Statistics, Coverage and Content Errors in Demographic data, Sampling and Non-sampling errors, Use of Balancing Equations.
Week 2-3	Chandrasekran-Deming formula, Population Composition, Dependency Ratio Errors in Age data, Evaluation of Age data, Myer's and UN Indices.
Week 4	Adjustment of Age data, Meaning of Vital Statistics, Vital events, Sources of data collection on Vital Statistics and errors they suffer from.
Week 5	Measurement of Population, Distinction between Rate and Ratio, Ratio of Vital events, Measures of Mortality: Crude Death Rate. Practical work.
Week 6	Specific Death Rate, Standardized Death Rate, Direct and Indirect Methods of Standardization, Practical work.
Week 7	Infant Mortality Rate, Relative Merits and Demerits of all the Rates. Practical work.
Week 8	Concepts of Stable and Stationary Populations, Central Mortality Rate, Force of Mortality. Approximate expressions for Force of Mortality.
Week 9	Introduction to Life Tables, Life Table Functions and Columns, Assumptions in the construction of Life Tables, Various relationships in the columns of a life table.
Week 10	Construction of Life Tables Uses of Life Tables, Concept of an Abridged Life Tables.Practical work.
Week 11	Life Table Functions and Columns of an Abridged Life Table, Types of Abridgement, Construction of an Abridged Life Table by Reed and Merrell method. Practical work.
Week 12	By Greville's method, and by King's method. Introduction to the concept of Fertility, Difference between Fertility and Fecundity. Practical work.
Week 13	Measures of Fertility: Crude Birth Rate, General Fertility Rate. Practical work.
Week 14	Specific Fertility Rate, Total Fertility Rate, Relative merits and demerits of all the Rates. Practical work.
Week 15	Measures of Population Growth: Crude Rate of Natural Increase, Pearl's Vital Index, Gross Reproduction Rate, Net Reproduction Rate, their relative merits and demerits. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Distinction between Vital Statistics and Demography.	Class room lectures and discussions.	Participation in class discussion.
I	Errors in Demographic data.	Class room lectures and discussions.	Participation in class discussion.
I	To check the completeness of registration data using Chandrasekaran-Deming formula.	Class room lectures and discussions.	Participation in class discussion.
I	Use of Myer's and UN indices in evaluating age data.	Class room lectures and discussions.	Participation in class discussion.

I	Use of Balancing equations, Population Composition and Dependency Ratio	Class room lectures and discussions.	Participation in class discussion.
	Understanding of the basic concepts in Demographic analysis and to take care of errors in demographic data.	Class Test/Assignment Work.	Depth of understanding in theoretical concepts.
II	Sources of data collection on Vital Statistics and errors therein.	Class room lectures and discussions.	Participation in class discussion.
II	Measurement of Population, Distinction between Rate and Ratio.	Class room lectures and discussions.	Participation in class discussion.
II	Basic measures of Mortality.	(i) Class room lectures and discussions. (ii) Practical work based on different measures of mortality.	Participation in class discussion.
	Understanding the primary sources of data collection on Vital events and learning some of the important measures of mortality.	Class Test/Assignment work.	(i) Depth of understanding in theoretical concepts. (ii) Ability to choose appropriate measures of mortality in different situations with clear reasoning.
III	Concepts of Stable and Stationary Populations.	Class room lectures and discussions.	Participation in class discussion.
III	Concept of Life Tables, their construction and uses.	(i) Class room lectures and discussions. (ii) Practical work based on the construction of life tables.	Participation in class discussion.
IV	Concept of Abridged life tables and their construction by Reed-Merrell method, Greville's method and King's Method.	(i) Class room lectures and discussions. (ii) Practical work based on the construction of Abridged life tables.	Participation in class discussion.
	Learning the concepts of Complete and Abridged Life Tables and their construction.	Class Test/Assignment work.	Depth of understanding in theoretical concepts.
IV	Basic measures of Fertility. Measures of Population Growth.	(i) Class room lectures and discussions. (ii) Practical work based on different measures of fertility and population growth.	Participation in class discussion.

	Learning the basic measures of Fertility and Population growth.	Class Test/Assignment work.	(i) Depth of understanding in theoretical concepts. (ii) Ability to choose appropriate measures of fertility and population growth in different situations with clear reasoning.
	Application of the concepts learnt. (Optional)	Project Work/Presentation.	Ability to apply the concepts learnt in real life.

Keywords: Demography and Population Statistics, Vital Statistics, Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality, Rate (IMR) and Standardized Death Rates, Stationary and Stable population Life Tables.

Bachelor of Science (Hons.) in Statistics
Semester V
STAT-DSE-2(A): Operations Research

Credits: 6 **Marks: 150**

Course Objectives:

The learning objectives include:
- To study various Operational Research Techniques and Models.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- The fundamental concepts of Operational Research Techniques
- Linear Programming.
- Transportation and assignment problems
- Game Theory
- Inventory Models

Contents:

UNIT I
Introduction to Operations Research (O.R.): Definition and phases of O.R.Model building, various types of O.R. problems.
Linear Programming Problem (L.P.P.): Mathematical formulation of the L.P.P, graphical solutions of L.P.P. Simplex method for solving L.P.P. Charne's M-technique for solving L.P.P. involving artificial variables. Special cases of L.P.P. Concept of Duality in L.P.P: Dual simplex method. Economic interpretation of Duality. Post-optimality analysis.

UNIT II
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, special cases of transportation problem.
Assignment problem: Hungarian method to find optimal assignment, special cases of assignment problem.

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

UNIT IV
Inventory Management: ABC inventory system, characteristics of inventory system. EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks.

SUGGESTED READINGS:

1. Taha, H. A. (2007). *Operations Research: An Introduction*, 8thEd., Prentice Hall of

India.

2. Swarup, K., Gupta, P.K. and Man Mohan (2007). *Operations Research*, 13th Ed., Sultan Chand and Sons.

PRACTICAL/ LAB WORK (Using TORA/WINQSB/LINGO)
List of Practicals:

1. Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables.
2. Identifying Special cases by Graphical and Simplex method and interpretation:
   a) Degenerate solution
   b) Unbounded solution
   c) Alternate solution
   d) Infeasible solution
3. Post-optimality:
   a) Addition of constraint
   b) Change in requirement vector
   c) Addition of new activity
   d) Change in cost vector
4. Allocation problem using Transportation model.
5. Allocation problem using Assignment model.
6. Networking problem:
   a) Minimal spanning tree problem
   b) Shortest route problem
7. Problems based on game matrix:
   a) Graphical solution to mx2 / 2xn rectangular game
   b) Mixed strategy
8. To find optimal inventory policy for EOQ models and its variations.
9. To solve all-units quantity discounts model.

Week-wise Teaching Plan

Week 1	Introduction to Operations Research, phases of O.R.
Week 2	Model building, various types of O.R. problems.
Week 3	Linear Programming Problem, Mathematical formulation of the L.P.P. Practical work.
Week 4-5	Graphical solutions of a L.P.P. Simplex method for solving L.P.P., Charne's M-technique for solving L.P.P. involving artificial variables. Practical work.
Week 6-8	Special cases of L.P.P. Concept of Duality in L.P.P., Dual simplex method. Post-optimality analysis. Practical work.
Week 9	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, special cases of transportation problem. Practical work.
Week 10	Assignment problem: Hungarian method to find optimal assignment, special cases of assignment problem. Practical work.
Week 11	Game theory: Rectangular game, minimax-maximin principle. Solution to rectangular game using graphical method, dominance and modified

	dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. Practical work.
Week12	Networking: Shortest route and minimal spanning tree problem. Practical work.
Week 13	Inventory Management: ABC inventory system, characteristics of inventory system. Practical work.
Week 14-15	EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction to Operations Research: Concepts and definition.	Class room lectures and discussions.	Participation in class discussion.
	Introduction to Linear Programming Problems. Special cases of L.P.P. Concept of Duality in L.P.P: Dual simplex method. Economic interpretation of Duality. Post-optimality analysis.	Class room lectures and discussions. Practical work.	Participation in class discussion.
A*	Understanding of LPP.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts
II	Transportation Problem.	Class room lectures and discussions. Practical work.	Participation in class discussion.
	Assignment Problem.	Class room lectures and discussions. Practical work.	Participation in class discussion.
III	Game Theory.	Class room lectures and discussions. Practical work.	Participation in class discussion.
	Networking.	Class room lectures and discussions. Practical work.	Participation in class discussion.
B*	Concepts of Transportation, assignment, game theory and Networking.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts
IV	Inventory Models.	Class room lectures and discussions. Practical work.	Participation in class discussion.

C*	Various inventory models.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keyword: Linear Programming Problem, Transportation Problem, Assignment Problem, Game theory, Networking, Various inventory models.

Bachelor of Science (Hons.) in Statistics

Semester V

STAT-DSE 2-(B): Econometrics

Credits: 6 **Marks: 150**

Course Objectives:

The learning objectives include**:**

- A broad knowledge of regression analysis relevant for analysing economic data.
- Interpretation and critical evaluation of the outcomes of empirical analysis.
- Distinguish the results of violating the assumptions of classical regression model.
- To judge the validity of the economic theories and carry out their evaluation in numerical terms.
- To extract useful information about important economic policy issues from the available data.

Course Learning Outcomes:

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

- The fundamental concepts of econometrics.
- Specification of the model.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.
- Autoregressive and Lag models.

Contents:

UNIT I

Introduction: Objective behind building econometric models, nature of econometrics, model building, role of econometrics. General linear model (GLM).Estimation under linear restrictions.

UNIT II

Multicollinearity: Introduction and concepts, detection of multicollinearity, consequences, tests and solutions of multicollinearity.

UNIT III

Generalized least squares estimation, Aitken estimators. Autocorrelation: concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

UNIT IV

Heteroscedastic disturbances: Concepts and efficiency of Aitken estimator with OLS estimator under heteroscedasticity. Consequences of heteroscedasticity. Tests and solutions

of heteroscedasticity. Autoregressive and Lag models.

SUGGESTED READINGS:

1. Gujarati, D. and Guneshker, S. (2007). *Basic Econometrics*, 4th Ed., McGraw Hill Companies.
2. Johnston, J. (1972). *Econometric Methods*, 2nd Ed., McGraw Hill International.
3. Koutsoyiannis, A. (2004). *Theory of Econometrics*, 2 Ed., Palgrave Macmillan Limited.
4. Maddala, G.S. and Lahiri, K. (2009). *Introduction to Econometrics*, 4 Ed., John Wiley & Sons.

PRACTICAL /LAB WORK
List of Practicals:

1. Problems based on estimation of General linear model.
2. Testing of parameters of General linear model.
3. Forecasting of General linear model.
4. Problems related to consequences of Multicollinearity.
5. Diagnostics of Multicollinearity.
6. Problems related to consequences of Autocorrelation (AR(I)).
7. Diagnostics of Autocorrelation.
8. Estimation of General linear model under Autocorrelation.
9. Problems related to consequences Heteroscedasticity.
10. Diagnostics of Heteroscedasticity.
11. Estimation of problems of General linear model under Heteroscedastic disturbance terms.
12. Problems concerning specification errors as a reason for induction of Autocorrelation, Heteroscdasticity and Multicollinearity.
13. Problems related to General linear model under (Aitken Estimation).
14. Problems on Autoregressive and Lag models.

Week-wise Teaching Plan

Week 1	Introduction and Objective behind building Econometric Models.
Week 1-3	General linear models. Practical work.
Week 4	Estimation under linear restrictions, Practical work.
Week 5-7	Multicollinearity, Concepts, Consequences, Tests for detection and Remedies. Practical work.
Week 8-9	Generalized least squares, Concepts**,** Aitken's Estimator, Prediction**.** Practical work.
Week 10-11	Autocorrelation, Concepts, Consequences, Tests for detection and Remedies. Practical work.
Week 12-13	Heteroscedasticity, Concepts, Consequences, Tests for detection and Remedies. Practical work.
Week 14-15	Autoregressive and Lag models, Concepts, Consequences and Remedies.Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction, fundamental concept of econometrics and objectives behind building econometric models.	Class room lectures and discussions dependent variable depends on two or more explanatory.	(i) Participation in class discussion. (ii) Identification of models.
I.	Specification of models in which the variables. Estimation of unkown parameters, their properties, adjusted and unadjused R^2	Class room lectures and discussions. Practical work based on multiple regression models.	(i) Participation in class discussion. (ii) Estimation, formulation of null hypotheses, interpretation of the estimated regression model and conclusion.
I	Estimation under linear restrictions.	Class room lectures and discussions. Practical work based on multiple regression models with addition linear restrictions on parameters.	(i) Participation in class discussion. (ii) Estimation, formulation of null hypotheses, interpretation of the estimated regression model and conclusion in case of multiple regression models with additional linear restrictions
II	Multicollinearity Concept Consequences Tests for detection of multicollinearity Remedies.	Class room lectures and discussions. Practical Work based on multiple regression models involving multicollinearity, its consequences and diagnostics	(i) Participation in class discussion. (ii) Estimation, formulation of null hypotheses, interpretation of the estimated regression model and conclusion in case of models with multicollinearity. (iii)Diagnosis of multicollinearity.
A*	Understanding of basic concept of econometrics, estimation of parameters of regression models and their significance tests, estimation under linear restriction, multicollinearity.	Class test / Assignment work.	Extent of clarity in theoretical concepts.
III	Generalized least squares estimation Concept	Class room lectures and discussions. Practical	(i) Participation in class discussion.

	Aitken's Estimators Preciction in case of GLSE.	work prediction in case of GLSE.	(ii) Estimation, prediction formulation of null hypotheses, interpretation of the estimated regression model and conclusion in case of GLSE.
III	Auto correlation/ Serial correlation Concept Consequences Tests for detection of Autocorrelation Remedies.	Classroom lectures and discussions. Practical work based on autocorrelated models.	(i) Participation in class discussion. (ii) Diagnosis, formulation of null hypotheses, interpretation of the estimated regression model and conclusion in case of autocorrelated models. (iii) Estimation with correction for autocorrelation.
IV	Heteroscedasticity Concept Consequences Tests for detection of Hetroscedasticity Remedies.	Classroom lectures and discussions Practical work based on heteroscedastic models.	(i) Participation in class discussion. (ii) Comparison of OLSE with or without hetroscedasticity and GLSE in case of hetroscedasticity. (iii) Diagnosis, formulation of null hypotheses, interpretation of the estimated regression model and conclusion in case of heteroscedastic models.
	Autoregressive and Lag models Concepts Consequences Remedies.	Classroom lectures and discussions Practical work based on Lag models.	(i) Participation in class discussion. (ii) Estimation in case of distributed lag models using Koyck's transformation.
B*	Understanding the concepts of GLSE, Autocorrelation, Hetroscedasticity and Lag Models.	Assignment work/ class test.	Extent of clarity in theoretical concepts.

*As per requirements of Internal Assessment for B.Sc.(Hons).

Keywords: Econometric models, General linear model, Generalized least squares estimation, Autocorrelation, Hetroscedasticity and Lag Models.

Bachelor of Science (Hons.) in Statistics

Semester VI
STAT-DSE-3(A): Actuarial Statistics

Credits: 6 **Marks: 150**

Course Objectives:
To learn advanced techniques in Actuarial Science with practical applications in daily life.

Course Learning Outcomes:
Tools for applying actuarial methods in phenomena for financial research and insurance. This includes computation of premiums and settlement of claims.

Contents:

UNIT I

Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.

UNIT II

Principles of Premium Calculation: Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

UNIT III

Survival Distribution and Life Tables: Uncertainty of age at death, survival function, time until-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics, assumptions for fractional age, some analytical laws of mortality.

UNIT IV

Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships. Life annuities: continuous life annuities, discrete life annuities, life annuities with periodic payments. Premiums: continuous and discrete premiums.

SUGGESTED READINGS:

1. Atkinson, M.E. and Dickson, D.C.M. (2011). *An Introduction to Actuarial Studies*, Elgar Publishing.

2. Dickson, C. M. D. (2005). *Insurance Risk and Ruin (International Series no.1 Actuarial Science),* Cambridge University Press. Bowers, N. L., Gerber, H. U., Hickman.

3. Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A. and Nesbitt, C.J. (1997). *Actuarial Mathematics, Society of Actuaries*, Itasca, Illinois, U.S.A.

PRACTICAL / LAB WORK
List of Practicals:

1. Risk computation for different utility models.
2. Discrete and continuous risk calculations.
3. Calculation of aggregate claims for collective risks.
4. Calculation of aggregate claim for individual risks.
5. Computing Ruin probabilities and aggregate losses.
6. Annuity and present value of contract.
7. Computing premium for different insurance schemes.
8. Practical based on life models and tables.

Week-wise Teaching Plan

Week 1	Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables.
Week 2- 3	Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.
Weeks 4 - 5	Principles of Premium Calculation: Properties of premium principles, examples of premium principles.
Weeks 6 - 7	Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.
Weeks 8 - 9	Survival Distribution and Life Tables: Uncertainty of age at death, survival function, timeuntil-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics, assumptions for fractional age, some analytical laws of mortality.
Weeks 10 - 11	Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships.
Weeks 12- 13	Life annuities: continuous life annuities, discrete life annuities, life annuities with periodic payments.
Week14	Premiums: continuous and discrete premiums.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
1.	Introduction to Insurance	Reinsurance, Utility Functions.	Computing moments of mixed random variables and applying

	Applications.		Expected Utility Criterion.
2.	Principles of Premium Calculation and Individual risk models.	Examples of premium principles. Models for individual claims.	Premium Calculation based on principles. Properties of premium principles. Computing the sum of independent claims, approximations and their applications.
3.	Survival Distribution and Life Tables.	Uncertainty of age at death, survival function, time until-death for a person, curate future lifetime, force of mortality, life tables with examples.	Deterministic survivorship group, life table characteristics, assumptions for fractional age, some analytical laws of mortality. Differentiate between Select and Ultimate Life Tables.
4.	Life Insurance.	Models for insurance Life annuities Computation of premiums.	Learning functions based on Insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships. Continuous life annuities, discrete life annuities and the respective premium calculations.

Keywords: Insurance, Utility functions, Premiums, Life Tables, Survival functions, Annuities.

Bachelor of Science (Hons.) in Statistics

Semester VI

STAT-DSE-3(B): Biostatistics and Survival Analysis

Credits: 6 **Marks: 150**

Course Objectives:

The learning objectives include:

- To analyse censored data and its application in public health.
- Estimate death probabilities by using the theory of competing risks in a cause-specific mortality study.
- Need of conducting clinical trials for introducing new drug.
- To compute probability of gametes in different generations under random mating.

Course Learning Outcomes:

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

- The fundamental concepts of survival functions and their interrelationship.
- Survival distributions and their applications.
- Handling censored data and estimating mean survival time.
- Actuarial and Kaplan-Meier methods (Non- parametric methods).
- Competing Risk Theory. Dependent and independent risk.
- Simple Stochastic epidemic model.
- Basic concept of genetics.
- Need of Clinical drug trials.

Contents:

UNIT I

Survival Analysis: Functions of survival times, survival distributions and their applications-exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function.Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.

UNIT II

Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations.Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods.Theory of independent and dependent risks. Bivariate normal dependent risk model.

UNIT III

Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition

and concept (without derivation). Duration of an epidemic.

UNIT IV

Statistical Genetics: Introduction, concepts-Genotype, Phenotype, Dominance, Recessiveness, Linkage and Recombination, Coupling and Repulsion. Mendelian laws of Heredity, Random mating, Gametic Array relation between genotypic array and gametic array under random mating. Distribution of genotypes under random mating. Clinical Trials: Planning and design of clinical trials, Phase I, II and III trials. Blinding: Single, Double, Triple.

SUGGESTED READINGS:

1. Biswas, S. (2007). *Applied Stochastic Processes*: *A Biostatistical and Population Oriented Approach*, Reprinted 2nd Ed., New Central Book Agency.
2. Elandt-Johnson R.C (1971). *Probability model and Statistical Methods in Genetics*, John Wiley & Sons.
3. Indrayan, A. (2008). *Medical Biostatistics*, 2nd Ed., Chapman and Hall/CRC.
4. Lee, E.T. and Wang, J.W. (2003). *Statistical Methods for Survival data Analysis*, 3rd Ed., John Wiley & Sons.
5. Narayan P. (1999). *Statistical Genetics*, New Age International Pvt. Ltd.
6. Miller, R. G. (2011). *Survival Analysis*. John Wiley & Sons.

PRACTICAL/LAB WORK
List of Practicals:

1. Estimation of survival function.
2. Determination of death density function and hazard function.
3. Identification of type of censoring and to estimate survival time for type I censored data.
4. Identification of type of censoring and to estimate survival time for type II censored data.
5. Identification of type of censoring and to estimate survival time for progressively type I censored data.
6. Estimation of mean survival time and variance of the estimator for type I censored data.
7. Estimation of mean survival time and variance of the estimator for type II censored data.
8. Estimation of mean survival time and variance of the estimator for progressively type I censored data.
9. To estimate the survival function and variance of the estimator using Non-parametric methods with Actuarial methods
10. To estimate the survival function and variance of the estimator using Non-parametric method with Kaplan-Meier method.
11. To estimate Crude probability of death.

12. To estimate Net-type I probability of death.
13. To estimate Net-type II probability of death.
14. To estimate partially crude probability of death.
15. To estimate gene frequencies F.

Week-wise Teaching Plan

Week 1-2	Survival Analysis: To study various survival functions and interrelationship between them. Introduction to various survival models.
Week 3-4	Censoring Schemes: Definition of censoring. Study of Type I, Type II and progressive or random censoring with biological examples.
Week 5-6	Non parametric Methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.
Week 7-8	Competing Risk Theory: Introduction of various measures of competing risk theory. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods.
Week 9	Theory of independent and dependent risks: Bivariate normal dependent risk model.
Week 10-11	Stochastic Epidemic Models: Definition of epidemic, susceptibles and infective. Simple and general epidemic model. Duration of an epidemic.
Week 12-13	Statistical Genetics: Introduction, concepts-Genotype, Phenotype, Dominance, Recessiveness, Linkage and Recombination, Coupling and Repulsion. Mendelian laws of Heredity, Random mating, Gametic array, relation between genotypic array and gametic array under random mating. Segregation matrix. Estimating probabilities of gametes for future generations.
Week 14	Clinical trials: Phases of clinical drug trial. Blinding.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Basic concepts of survival functions.	Class room lectures and discussions.	Participation in class discussion.
I	Survival distributions and their applications.Bath tub model.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
I	Censored data: Type I, Type II and progressive or random censoring with biological examples.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
I	Estimation of survival time under censoring schemes.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
I	Actuarial and Kaplan-Meier methods for estimating survival function and	(i) Class room lectures and	Participation in class discussion.

	variance of the Estimator.	discussions. (ii) Practical work.	
II	Measurement of probability of death under competing risks.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Inter-relationship between different measures of probability of death.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Independent and dependent risks.	(i) Class room lectures and discussions.	Participation in class discussion.
			Class test/assignment on first two units.
III	Epidemic models. General epidemic model definition. Simple epidemic models & duration of an epidemic	(i) Class room lectures and discussions.	Participation in class discussion.
IV	Statistical Genetics.	(i) Class room lectures and discussions. (ii) Practical work	Participation in class discussion.
IV	Clinical Drug Trials.	(i) Class room lectures and discussions.	Participation in class discussion.
IV	Blinding.	(i) Class room lectures and discussions.	Participation in class discussion.
			Class test/assignment on last two units.

Keywords: Censored data, Actuarial and Kaplan-Meier methods, Survival function, Epidemic models, Clinical Drug Trials.

Bachelor of Science (Hons.) in Statistics
Semester VI
STAT-DSE-4(A): Financial Statistics

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To understand financial markets and in particular, derivative markets.
- To develop an understanding of stochastic calculus.
- To apply the techniques of stochastic calculus to price the products of derivative markets.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- The fundamental concepts of investments and products of financial markets.
- Derivative markets.
- Continuous time stochastic processes.
- Brownian motion and Wiener process.
- Stochastic calculus and Itô Calculus.
- Stochastic differential equations.
- Black Scholes' model.
- Hedging of financial portfolios.

Contents:

UNIT I

Introduction to investment and markets: Cash flows- deterministic and random, Basic theory of interest, bonds and yields, Term structure of interest rates, Portfolio Theory.

UNIT II

Introduction to derivatives, Tools Needed for Option Pricing: Forward contracts, spot price, forward price, future price, Call and put options, Zero-coupon bonds and discount bonds, Pricing derivatives: Arbitrage relations and perfect financial markets, Pricing futures, Put-call parity for European and American options, Relationship between strike price and option price. Discrete Stochastic Processes, Binomial processes, General random walks, Geometric random walks, Binomial models, Trinomial models.

UNIT III

Continuous time processes – Brownian motion, Geometric Brownian motion, Wiener process; Introduction to stochastic calculus: stochastic integration, stochastic differential equations and their solutions; Itô's lemma.

UNIT IV

Intrinsic of option markets: Black-Scholes differential equation, Black-Scholes formula for European and American options, Implied volatility, Binomial Model for European options:

Cox-Ross-Rubinstein approach to option pricing. Discrete dividends, Trinomial model for American options, Hedging portfolios: Delta, Gamma and Theta hedging.

SUGGESTED READINGS:

1. David, G. L. (2015). *Investment Science*, Oxford University Press(South Asian edition)
2. Franke, J., Hardle, W.K. and Hafner, C.M. (2011). *Statistics of Financial Markets: An Introduction*, 3rd Ed., Springer Publications.
3. Stanley, L. S. (2012). *A Course on Statistics for Finance*, Chapman and Hall/CRC.

PRACTICAL / LAB WORK
List of Practicals:

Mode of Conducting Practical Examination: The students should be encouraged to perform practical problems on computers using whatsoever software/package as far as possible.

1. To compute NPV and to obtain IRR of the investments.
2. To verify "no arbitrage" principle.
3. To price future / forward contracts.
4. To construct binomial trees and to evaluate options using these trees.
5. Simulation of continuous time stochastic processes.
6. To price options using Black – Scholes formula.
7. Pricing of options using discrete time models.
8. Impact of dividend on option prices.
9. Call-put parity for options.
10. Application of Greeks to hedge investment portfolios.

Week-wise Teaching Plan

Week 1-3	Introduction to investment and markets: Cash flows- deterministic and random, basic theory of interest, bonds and yields, term structure of interest rates, portfolio theory.
Week 4-7	Introduction to derivatives, Tools Needed For Option Pricing: Forward contracts, spot price, forward price, future price. Call and put options, zero-coupon bonds and discount bonds, Pricing derivatives: Arbitrage relations and perfect financial markets, pricing futures, put-call parity for European and American options, relationship between strike price and option price.
Week 8	Discrete Stochastic Processes, Binomial processes, General random walks, Geometric random walks, Binomial models, Trinomial models.
Week 9-10	Continuous time processes - Brownian motion, geometric Brownian motion, Wiener process; Introduction to stochastic calculus.
Week 11-12	Stochastic differential equations and their solutions; Itô's lemma.
Week 13-15	Intrinsic of option markets: Black-Scholes differential equation, Black-Scholes formula for European and American options, Implied volatility, Binomial Model for European options: Cox-Ross-Rubinstein approach to option pricing. Discrete dividends, Trinomial model for American options, Hedging portfolios: Delta, Gamma and Theta hedging.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	The fundamental concepts of investments.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
II	Products of financial markets.	Class room lectures and discussions.	Participation in class discussion.
II	Derivative markets.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
III	Continuous time stochastic processes.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
III	Brownian motion and Wiener process.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
III	Stochastic calculus and Itô Calculus.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
			Class test/assignment on first two units
III	Stochastic differential equations.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
IV	Black Scholes' model	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
IV	Hedging of financial portfolios.	(i) Class room lectures and discussions. (ii) Practical work.	Participation in class discussion.
			Class test/assignment on last two units

Keywords: Financial Markets, Assets, Rate of Interest,Returns, Derivatives, Forwards, Futures, Options, Risk and Risk Management, Stochastic Calculus, Wiener process, Ito lemma, Pricing derivatives, Black-Scholes' option pricing formula, CRR model, Binomial Model, Hedging.

Bachelor of Science (Hons.) in Statistics
Semester VI
STAT-DSE-4(B): Project Work

Credits: 6

Course Objectives:

The aim of the course is to initiate students to write and present a statistical report, under the supervision of a faculty, on some area of human interest. The project work will provide hands on training to the students to deal with data emanating from some real life situation and propel them to dwell on some theory or relate it to some theoretical concepts.

Course Learning Outcomes:
The project work will provide hands on training to the students to deal with data and relate it to some theoretical concepts.

Contents:

UNIT I

Define the scope and objectives of the research project. Objectives of project, project work approaches, significance of project work, defining the project work, necessity of defining the project work, technique Involved, Census and Sample Survey, implications of a sample design, steps in sampling design, criteria of selecting a sampling procedure, Measurement and Scaling Techniques Measurement Scales, sources of error in measurement, Tests of sound measurement, scaling, scale classification, scale construction Techniques.

UNIT II

Project Schedule Methods of data collection, Collection of Primary Data, observation method, interview method, collection of data through questionnaires, collection of data through schedules, difference between questionnaires and schedules, some other methods of data collection, collection of secondary data, selection of appropriate method for data collection.

UNIT III

Processing operations, some problems in processing, elements/types of analysis, need for sampling, important sampling distributions, estimation, sample size and its determination, determination of sample size through the approach based on precision rate and confidence level, determination of samples size through the approach based on Bayesian Statistics, testing of Hypotheses, basic concepts concerning testing of Hypotheses, procedure for Hypothesis testing, flow diagram for Hypothesis testing, measuring the power of a Hypothesis test, tests of Hypotheses, parametric and non-parametric, limitations of the tests of Hypotheses, Analysis of Variance (ANOVA), the basic principle of ANOVA, ANOVA technique, Analysis of Co-variance (ANOCOVA), assumptions in ANOCOVA, Multivariate Techniques, methods of Factor Analysis, rotation in Factor Analysis, Processing and Analysis of Data.

UNIT IV

Meaning of Interpretation,Technique of Interpretation, precaution in Interpretation, significance of report project writing, different steps in writing project report, layout of the project report, types of reports, oral presentation, Mechanics of writing a research report, precautions for Writing project reports, conclusions. Interpretation and Report Writing.

SUGGESTED READINGS:

1. Cochran, W.G. and Cox, G.M. (1959): *Experimental Design*. Asia Publishing House.
2. Kothari, C.R. (2015): *Research Methodology: Methods and Techniques*, 3rd Edition reprint, New Age International Publishers.
3. Kumar, R (2011): *Research Methodology: A Step - by - Step Guide for Beginners*, SAGE publications.
4. Cochran, W.G. (2011): *Sampling Techniques* (3rd Ed.), Wiley Eastern John Wiley and Sons.
5. Murthy M.N. (1977): *Sampling Theory & Statistical Methods*, Statistical Pub. Society, Calcutta.
6. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S. and Asok, C. (1984): *Sampling Theories of Survey with Application,* IOWA State University Press and Indian Society of Agricultural Statistics.
7. Gujarati, D. and Sangeetha, S. (2007): *Basic Econometrics*, 4 Edition, McGraw Hill Companies.

Additional Resources:

1. Journal of Statistical Theory and Practice.
2. Communication in Statistics- Theory and Methods.
3. Journal of Statistical Theory and Applications.
4. Journal of Medical Statistics.

PRACTICAL / LAB WORK

The project work itself a practical problem and it relates to some theoretical concepts.

Week-wise Teaching Plan:

1. Validity of the project and how it can be used for benefit to the society.
2. To study step by step project work.

Facilitating the Achievement of Course Learning Outcomes:

As per their understanding and project work done by students.

Keywords: Project

Skill Enhancement Courses

Bachelor of Science (Hons.) in Statistics
STAT- SEC-1: Data Analysis Using Software Packages (SPSS)

Credits: 4 **Marks: 100**

Course Objectives:
The learning objectives include:

- To understand SPSS and its roles in problem solving.
- To understand data handling and its analysis.
- Learning the basic statistical software will help students to easily switch over to any other statistical software in future.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of SPSS.

Contents:

UNIT I

SPSS Basics, plot a graph viz. histograms (equal class intervals and unequal class intervals), box plot, bar graphs, line graphs, stem-leaf, frequency polygon, pie chart, ogives with graphical summaries of data.

UNIT II

Generate automated reports giving detailed descriptive statistics, correlation and lines of regression.

UNIT III

Random number generation using different probability distributions and sampling procedures. Fitting of polynomials and exponential curves. Problems based on fitting of suitable distribution. Normal probability plot.

UNIT IV

Simple analysis, create and manage statistical analysis projects, import data, Basics of statistical inference in order to understand hypothesis testing and compute p-values and confidence intervals. Comparison of several means. Syntax code editing.

SUGGESTED READINGS:

1. Knapp, H. (2014). *Introductory Statistics Using SPSS*, SAGE Publications India Private Ltd.
2. Cunningham, J.B. and Aldrich, J.O. (2014): *Using SPSS- An Interactive Hands-On Approach,* SAGE Publications India Private Ltd.

PRACTICAL/LAB WORK
List of Practicals:

1. Draw histogram for equal/unequal width class interval, Stem and Leaf plot,Box plot frequency polygon, pie chart, bar graphs, line charts, Ogive.
2. Construct frequency table using recode (having equal and unequal interval) and visual binning.
3. Compute descriptive statistics for raw data and grouped data and interpret by computing coefficient of variation, skewness and kurtosis.
4. Use of count, compute, compute with if and rank feature.
5. Calculate correlation coefficient (Karl Pearson), Spearman's rank correlation coefficient, Multiple and Partial correlation coefficient and fitting of two lines of regression and their plot.
6. Generation of random sample from Binomial, Poisson, Negative binomial, Uniform, Exponential, Normal, Gamma chi-square t and F distributions Stem and Leaf plots and Box Plots for these random Samples.
7. CLT for binomial and Poisson distribution. (Generate samples, compute their means and draw histogram along with normal curve; normal probability plot)
8. Compute cdf $F(x) = P(X \leq x)$ for random sample of observations drawn from theoretical distributions.
9. Draw simple random sample with/without replacement, stratified and systematic sample from a given data set and compute various measures by select cases and (or) complex sampling.
10. Fit linear, quadratic and exponential curve and find which one is best suited from the graph.
11. Obtain sampling distribution of sample mean in sampling from various distributions (sampling distribution can be shown to be normal by normal probability plot) as well as using recoding option and then computing quantiles.
12. Construct bivariate distribution using recode.
13. t-test for single mean, difference of means and Paired t-test, F-Test, Chi Square test for independence of attributes for raw data (using crosstab feature) and Chi Square test for independence of attributes (given contingency table), chi square test for goodness of fit and comparison of several means (ANOVA).
14. Generate a random sample and fit Binomial, Poisson and Negative Binomial distribution.
15. Comparison of series when (a) with missing observation (b) when missing observation is replaced by a constant (c) when missing observation is replaced by an average (mean, median or mode).
16. How to edit syntax, save it and retrieve it for subsequent analyses with the help of relevant example and Data import from other packages and export to other packages.

NOTE:

1. Students may be encouraged to complete at least one project (given some large data, students can analyze and prepare a report).
2. There will be no separate end semester theory examination in this paper and the evaluation will be done only through end semester practical examination, besides the internal assessment of 25 marks.

Week-wise Teaching Plan

Week 1	Introduction to SPSS: how to enter variable names and data. Generate a table of statistics and graph summarizing those statistics. Navigate the Variable View and Data View screens. Investigations of main menu and data editor tool bar. Save and open data and output files. To distinguish between variables measured at the nominal, ordinal and scale levels of measurements. To enter variables and their attributes.
Week 2	Use of count, compute, compute with if and rank feature.
Week 2-3	Concept of recode and visual binning, generation of frequency tables, To calculate measures of central tendency and measure of dispersion.
Week 4	To create basic graphs using Legacy Dialogs and Chart Builder methods, to edit basic graphs.
Week 5	Computation and interpretation of correlation coefficient (Pearson's and Spearman's). Test of significance for Pearson's correlation coefficient. Multiple and Partial correlation coefficients.
Week 6	Fitting of polynomial and exponential curves using built in functions. Fitting of most suitable curve.
Week 7	Fitting and plotting of regression lines.
Week 8	Generation of random sample from different distribution and their graphic representation.
Week 9	Calculations of CDF, to show CLT for different distributions. To plot the Normal Probability plot.
Week 10	Importing and Exporting files. How to deal with missing observations.
Week 11-12	Basics of Statistical inference for hypothesis testing, compute p-values and confidence interval. Testing of hypotheses-one sample t-test, paired sample t-test, Independent sample t-test, Test for comparison of several means. Chi Square test for Goodness of Fit.
Week 13	Constructing bivariate table and Chi Square test of Independence of attributes.
Week 14-15	How to select a SRS, systematic and stratified sample from a given population.
Week 15	Code editing using syntax file.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction to SPSS.	Class room lectures and Practical work.	Participation in class discussion and completion of assignment.
I	Exposure to the descriptive statistics and different types of graphs.	Class room lectures and Practical work.	Participation in class discussion and completion of assignment.
II	Generation of reports with detailed descriptive statistics.	Class room lectures and Practical work.	Participation in class discussion and completion of assignment. Formulation of null hypotheses analyse and interpret the results.
II	Understanding of the concept of different		

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
	correlation coefficients.		
II	Concept of lines of Regression.		
III	Sampling procedures	Class room lectures and Practical work.	Participation in class discussion and completion of assignment.
III	Fitting of curves		
III	Generation of random numbers using different probability distributions.		
IV	Understanding of Hypothesis Testing.	Project Work and its presentation.	Identification of appropriate Test of Hypothesis, formulation of null hypothesis. Ability to analyse the data, interpret the result and draw conclusion.

Keywords: SPSS Basics**,** Box plot, Bar graphs, line graphs, Stem-leaf, Fitting of polynomial, Statistical inference, Code editing using syntax file.

Bachelor of Science (Hons.) in Statistics

STAT-SEC-1: Data Analysis Using Software Packages (MATLAB)

Credits: 4 **Marks: 100**

Course Objectives:

The objective of this course is to introduce MATLAB, MATLAB programming and statistics toolbox.

Course Learning Outcomes:

After completing this course, students will possess skills concerning

- Basic programming in MATLAB.
- Ability to solve statistical problems, numerical methods.
- Basic symbolic computations.

Contents:

UNIT I

Introduction –Desktop environment; help system. Data in MATLAB – Data objects in base MATLAB (scalars, characters, Arrays, strings, Cell-arrays, Structures, excluding Tables); Variables; Assignment statements; System variables; Accessing data elements; Example of Joining data sets. Data Import and Export – Text files, Comma-Separated Values files, Spreadsheet files. Miscellaneous Topics – workspace, dir, cd, copyfile, delete, what, who, whos, which, clear, close, clc and path commands; punctuation. Arithmetic operators; Functions in MATLAB – introduction, syntax for definition and use.
Visualizing Data: Basics – graph2d, graph3d; plot function – 2D, 3D, Scatter Plots; simple plot editing. Plots in 2D – Adding title, Labels, Legends; fplot; logarithmic plots; plotyy; axis and axes commands; subplot function; ginput; Discrete plots using stem, stair; Statistical plots.

UNIT II

Descriptive Statistics- Measures of Location – Mean, Median, Mode. Measures of Dispersion – Range, Variance, Standard Deviation; Covariance (cov) and Correlation (corrcoef). Quantiles, Interquartile range, Skewness. Visualizing the Data distribution through Histogram (hist and histfit), normal probability plot (normplot) and Boxplot.

UNIT III

Probability distributions- Random number generation in Base MATLAB using rand and. Applications.

UNIT IV

Using statistics toolbox regarding computations relating to theoretical distributions: "…pdf", "…cdf", "…inv", "…stat", "…fit", "…rnd" for Continuous distributions (beta, Chi-square, exponential, gamma, Lognormal, Normal, Uniform); for Discrete distributions (binomial, Geometric, Poisson, Uniform).

Hypothesis Testing-Basic concepts – Right-tail, Left-tail, Two-tail region; Type-I & Type-II error, p-value; Confidence Intervals. Example of the z-Test. Elementary Symbolic Computations. ODE.

SUGGESTED READINGS:

1. D. Ray and S. Dey (2018): *A text book on MATLAB Programming for Engineering and Science*, 2nd ed. Shroff Publishers and Distributors, Pvt. Ltd., Navi Mumbai.
2. M.J. Cho and W. L. Martinez (2014). *Statistics in MATLAB: A Primer,* Chapman & Hall/CRC
3. Singh, Y. K. and Chaudhuri, B. B. (2007). *MATLAB Programming,* PHI, New Delhi

PRACTICAL/LAB WORK
List of Practicals

1. To solve various problems of Matrix Theory, Algebra, Calculus
2. To solve differential equations
3. To calculate some descriptive statistics
4. To plot scatter diagram
5. To obtain the plot of given equation
6. To plot normal distribution and its derivatives, truncated normal distribution
7. To plot contour of bivariate normal distribution
8. To generate random sample from various continuous& discrete distributions
9. To investigate the shape of gamma distribution
10. To investigate the shape of 3-D surface
11. To develop a function for computation of e^x
12. To develop a function for measures of location
13. To develop a function for measures of dispersion
14. To generate random walk for N steps and plot them

NOTE:

There will be no separate end semester theory examination in this paper and the evaluation will be done only through end semester practical examination, besides the internal assessment of 25 marks.

Week-wise Teaching Plan:

Week 1-3	Introduction. Data objects in base MATLAB.
Week 3-4	Variables; Assignment statements; System variables; Accessing data elements; Example of Joining data sets.
Week 5	Data Import and Export – Text files, Comma-Separated Values files, Spreadsheet files.
Week 6	Workspace, dir, cd, copyfile, delete, what, who, whos, which, clear, close, clc and path commands; punctuation. Arithmetic operators.
Week 7	Functions in MATLAB – introduction, syntax for definition and use.
Week 8	Visualizing Data.
Week 9-10	Descriptive Statistics- Measures of Location & Dispersion. Quantiles, Interquartile range, Skewness. Visualizing the Data distribution through

	Histogram (hist and histfit), normal probability plot and Boxplot.
Week 10-11	Random number generation in Base MATLAB using rand, randn. Applications.
Week 11-13	Using statistics toolbox. Hypothesis Testing
Week 13-14	Elementary Symbolic Computations. ODE

Facilitating the achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction. Data objects in base MATLAB. Variables; Assignment statements; syntax	(i) Class room lectures and discussions. (ii) Practical work	(i) Participation in class discussion. (ii) Based on problem solving in Lab.
	Data Import and Export		
	Common system commands; Functions in MATLAB		
	Visualizing Data		
II	Descriptive Statistics. Quantiles, Interquartile range, Skewness.	(i) Class room lectures and discussions. (ii) Practical work.	(i) Participation in class discussion (ii) Based on problem solving in Lab.
	Histogram (hist and histfit), normal probability plot (normplot) and Boxplot		
A*	Appraisal-First	Class Test/ Assignment work	Extent of clarity in theoretical& practical concepts
III	Random number generation in Base MATLAB using rand, randn. Applications	(i) Class room lectures and discussions. (ii) Practical work based.	(i) Participation in class discussion. (ii) Based on problem solving in Lab. (iii) Ability to solve application problem
IV	Toolboxes in MATLAB, Using statistics toolbox		
	Hypothesis Testing; Confidence Intervals		
	Elementary Symbolic Computations. ODE.		
B*	Appraisal-Second	Class Test/ Assignment work	Extent of clarity in theoretical& practical concepts.

*As per requirements of Internal Assessment for B.Sc. (Honrs).

Keywords: Data objects in base MATLAB, Variables, Assignment statements, Syntax, Functions in MATLAB, Random number generation, Hypothesis Testing, Toolboxes in MATLAB.

Bachelor of Science (Hons.) in Statistics

STAT-SEC-2: Statistical Data Analysis Using R

Credits: 4 **Marks: 100**

Course Objectives:
The learning objectives include:

- Review and expand upon core topics in probability and statistics.
- Practice of graphical interpretation, probability distribution and data analysis using `R'.

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

- Various Graphical representation and interpretation of data.
- Automated reports giving detailed descriptive statistics.
- Understanding data and fitting suitable distribution.
- Testing of hypothesis, p-value and confidence interval.
- Random number generation and sampling procedures.
- Importing data, Code editing in R and flow controls if (), for (), while ().

Contents:

UNIT I

Learn how to load data, plot a graph: bar-plot, pie-chart, and box plot, stem-leaf, histograms (equal class intervals and unequal class intervals), frequency polygon, ogives with graphical summaries of data.

UNIT II

Generate automated reports giving detailed descriptive statistics, scatter plot; correlation and lines of regression, curvilinear regression.

UNIT III

Introduction to flow control: if (), for () and while () loop; Random number generation and sampling procedures. Application problems based on fitting of suitable distribution, Q-Q plot, Multiple Regression.

UNIT IV

Basics of statistical inference in order to understand hypothesis testing, compute p-values and confidence intervals. Simple analysis and create and manage statistical analysis projects, import data, code editing.

SUGGESTED READINGS:

1. Braun, W. J., and Murdoch, D. J. (2007). *A First Course in Statistical Programming with R*. Cambridge University Press. New York.
2. Crawley, M. J. (2012). *The R Book*. 2nd Ed., John Wiley & Sons.
3. Dalgaard, P. (2008). *Introductory Statistics with R*. 2nd Ed., Springer.
4. Gardener, M. (2012). *Beginning R: The Statistical Programming Language*, Wiley Publications.

Week-wise Teaching Plan

Week 1	Introduction to R, Installation of packages and modules, loading of data, playing with arithmetic expressions. Introduction to data types.
Week 2-4	Graphical representation and interpretation viz. bar-plot, pie-chart, and box plot, stem-leaf, histograms (equal class intervals and unequal class intervals), frequency polygon, ogives with graphical summaries of data. Practical work.
Week 5	Generate automated reports giving detailed descriptive statistics. Practical work.
Week 6-7	Import data, code editing, Scatter plot; correlation and lines of regression, Curvilinear regression. Practical work.
Week 8-9	User defined functions, Introduction to flow control: if(), for() and while() loop. Practical work.
Week 10	Random number generation and sampling procedures. Application problems based on fitting of suitable distribution. Practical work.
Week 11	Q-Q plot, Multiple Regression. Practical work.
Week 12-13	Basics of statistical inference in order to understand hypothesis testing, compute p-values and confidence intervals. Practical work.
Week 14-15	Simple analysis and create and manage statistical analysis projects.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Graphical representation and interpretation of data.	(i) Class room lectures and discussions. (ii) Practical work based on data representation in the form of frequency distribution.	Participation in class discussion. Identification of form of data and representation of central tendency, dispersion and outliers in the data.
A*	Understanding data and graphical representation.	Class Test/ Assignment work.	Extent of clarity of theoretical concepts studied in core papers with respect to graphical representation of data.
II	Descriptive Statistics	(i) Class room	(i) Participation in class

	and summaries of data.	lectures and discussions. (ii) Practical work based on the probability distributions and inferential Statistics.	discussion. (ii) Identification of probability distribution, formulation of null hypothesis, appropriate analysis, interpretation of results and conclusion. Extent of clarity in theoretical concepts studied in core topics in probability and statistics.
III	Flow controls if, for, while.		
III	Understanding data and fitting suitable distribution.		
III	Random number generation and sampling procedures.		
IV	Importing data, Code editing in R.		
IV	Testing of hypothesis, p-value and confidence interval.		
B*	Understanding coding, hypothesis testing, sampling procedures and probability distributions.	Class Test/ Assignment work.	Extent of clarity of theoretical concepts studied in core papers with respect to data analysis.
C*	Simple analysis and create and manage statistical analysis projects.	Project Work and its presentation.	Ability to understand and draw inferential conclusion using data.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Bar-plot, Pie-chart, Box plot, Stem-leaf, Histograms (equal class intervals and unequal class intervals), Frequency polygon, Ogives with graphical summaries of data.

Bachelor of Science (Hons.) in Statistics
STAT-SEC-3: Statistical Techniques for Research Methods

Credits: 4 **Marks: 100**

Course Objectives:
The learning objectives include:

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses and interpretation.

Course Learning Outcomes:
After completion of this course, students should have developed a clear understanding of:

- Research methodology.
- Research Problem.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

Contents:

UNIT I

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

UNIT II

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

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

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.

SUGGESTED READINGS:

1. Kothari, C.R. (2015). *Research Methodology: Methods and Techniques*, 3rd Edition reprint, New Age International Publishers.
2. Kumar, R. (2011). *Research Methodology: A Step-by-Step Guide for Beginners*, SAGE publications.
3. Cochran, W.G. and Cox, G.M. (1959). *Experimental Design*. Asia Publishing House.

Project Work (using spread sheet and statistical packages –SPSS/R)

Week- wise Teaching Plan

Week 1	Research Methodology: Introduction, meaning of research, objectives of research, types of research, research approaches, research methods versus research methodology, research process. Research Problem: Importance and techniques involved in defining a research problem.
Week 2	Research Design: Important concepts relating to research design, different research design and basic principles of experimental design.
Week 3	Design of Sample Surveys: Census and sample survey, implications of a sample design, probability sampling, non-probability sampling. Practical Work-Introduction to a software package.
Week 4	Methods Of Data Collection: Primary and Secondary data, Collection of primary data, difference between questionnaires and schedules. Guidelines for constructing questionnaire and successful interviewing. Practical work.
Week 5	Data Preparation: Processing and Analysis of Data: Processing Operations, measures of central tendency and dispersion. Practical work.
Week 6	Sampling Fundamentals: Sampling and non-sampling errors, sampling distributions. Point and interval estimation. Practical work.
Week 7	Sampling Fundamentals: Point and interval estimation.Sample size and its determination. Practical work.
Week 8	Testing of Hypothesis: Basic concepts concerning testing of hypothesis. Test statistic, critical region, critical value and decision rule. Project work.
Week 9	Testing of Hypothesis: Important Parametric Tests. Hypothesis testing of Means, and Proportions. Project work /Practical work.
Week 10	Testing of Hypothesis: Hypothesis testing for Difference between Means and Proportions. Project work/ Practical work.
Week 11	Testing of Hypothesis: Hypothesis testing for variance and equality of variances of two normal populations. Project work/ Practical work
Week 12	Chi-Square Tests: Test of difference of more than two proportions, Test of Independence of Attributes. Project work/ Practical work.
Week 13	Chi-Square Tests: Test of Goodness of Fit. Interpretation and Report Writing: Meaning and technique of interpretation. Project Work/ Practical work.
Week 14	Interpretation and Report Writing: Steps involved in report writing and it's significance. Layout, mechanics and precautions for writing research reports. Submission of Project work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction to research methodology and technique of defining a research problem.	Class room lectures and discussions.	Participation in class discussion.
I	The basic principles of Experimental Designs and introduction to different research designs.	Class room lectures and discussions.	Participation in class discussion.
II	Concept of Sampling Designs.	Class room lectures and discussions.	(i) Participation in class discussion. (ii) Identification of a research problem.
II	Methods of Data Collection.		
II	Guidelines for constructing Questionnaire and successful Interviewing.		
II	Guidelines for constructing Questionnaire and successful Interviewing.		
A*	Understanding of fundamentals of research methodology, research problem and research designs.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
III	Understanding of Processing Operations.	Class room lectures and discussions. Practical work using a software package.	(i) Participation in class discussion. (ii) Development of a Questionnaire. Identification of appropriate Test of Hypothesis, formulation of null hypothesis, appropriate analysis, interpretation of results and conclusion.
III	Descriptive and Inferential Analysis of data.		
III	Sampling Distributions. Parametric Tests of Hypotheses. Chi -square Test.		
B*	Understanding of Hypothesis Testing.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
IV	Application of research methodology.	Project Work and its presentation.	Ability to analyse the data, interpret the result and draw conclusion.

* As per requirements of Internal Assessment forB.Sc. (Hons.).

Keywords: Research methodology, Research Design, Data Collection, Questionnaire, Hypothesis, Interpretation and Report Writing.

Bachelor of Science (Hons.) in Statistics
STAT SEC-4: Statistical Simulation Techniques

Credits: 4 **Marks: 100**

Course Objectives:
The objective of this course is to introduce the nuances of techniques involved in simulation studies as applicable to modeling of systems. The programming implementations will be completed using C/MATLAB/R.

Course Learning Outcomes:
After completing this course, students will possess skills concerning:

- Use of simulation to understand the behavior of real world systems.
- Ability to generate Pseudo-random numbers by the different methods.
- Random variable generation from theoretical distributions.
- Use of Monte Carlo methods and regenerative simulation.
- Ability to develop programs for the purpose of simulation.

Contents:

Unit I

Introduction: Systems, Models, Simulation and Monte Carlo Methods. Pseudo-random number generators; Statistical tests of Pseudo-random numbers.

Unit II

Random variate generation-The inverse transform method, Acceptance-Rejection method, Composition Method. Simulation of random vectors. Generation from Discrete and Continuous distributions; Transformation of random variables.

Unit III

Monte Carlo integration; Variance reduction techniques.

Unit IV

Regenerative simulation; Point Estimators and Confidence Intervals.

SUGGESTED READINGS:

4. Fishman, G.S. (1996). *Monte Carlo-Concepts, Algorithms and Applications*, Springer.
5. Rubinstein, R.Y. (1981). *Simulation and the Monte Carlo Methods*, Wiley.

6. Voss, J. (2014). *An introduction to statistical computing: a simulation-based approach,* Wiley series in computational statistics.

PRACTICAL/LAB WORK
List of Practicals:

1. Pseudo random number generators.
2. Generation of $U(0,1)$.
3. Problems based on statistical tests.
4. Application to standard statistical distributions (discrete and continuous):
   a) The inverse transform method.
   b) Acceptance-Rejection method.
5. Problems based on Composition Method.
6. Problems based on Monte Carlo integration.
7. Problems based on Regenerative methods.

Week-wise Teaching Plan

Week 1	Introduction: Systems, Models, Simulation and Monte Carlo Methods.
Week 2-3	Pseudo-random number generators. Practical work.
Week 4-5	Statistical tests of Pseudo-random numbers. Practical work.
Week 5-7	The Inverse transform& Acceptance-Rejection methods method-discrete distributions. Practical work.
Week 7-9	Inverse transform& Acceptance-Rejection methods-continuous distributions. Practical work.
Week 10	Composition Method. Practical work.
Week 11-12	Monte Carlo integration; Variance reduction techniques. Practical work.
Week 13-14	Regenerative simulation; Point Estimators and Confidence Intervals. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction: Systems, Models, Simulation and Monte Carlo Methods.	(i) Class room lectures and discussions. (ii) Practical work.	(i) Participation in class discussion. (ii) Physical experimentation.
	Pseudo-random number generators.		
	Statistical tests of Pseudo-random numbers.		
II	Pseudo-random number generators.	(i) Class room lectures and	(i) Participation in class discussion.

	The inverse transform method-discrete distributions.	discussions. (ii) Practical work.	(ii) Identification of random number, Monte-Carlo method, simulation worksheet, appropriate analysis, interpretation of results and conclusion.
	The inverse transform method: continuous distributions.		
	Composition Method.		
A*	Appraisal-First.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
III	Monte Carlo integration.	(i) Class room lectures and discussions. (ii) Practical work based.	(i) Participation in class discussion. (ii) Identification of random number, Monte- Carlo method, simulation worksheet, appropriate analysis, interpretation of results and conclusion.
	Variance reduction techniques.		
IV	Regenerative simulation; Point Estimators and Confidence Intervals.		
B*	Appraisal-Second.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Simulation and Monte Carlo Methods, Random variate generation, Monte Carlo integration, Regenerative simulation.

Generic Elective Papers

Bachelor of Science (Hons.) in Statistics
STAT-GE-1: Statistical Methods

Credits: 6 **Marks:150**

Course Objectives:
The learning objectives include**:**

- Acquainting the students with various statistical methods.
- To introduce students to different measurement scales, qualitative and quantitative and discrete and continuous data.
- To help students to organize data into frequency distribution graphs, including bar graphs, histograms, polygons, and Ogives.
- Students should be able to understand the purpose for measuring central tendency, variation, skewness and kurtosis and should be able to compute them as well.
- Students should be able to understand and compute various statistical measures of correlation, fitting of curve and regression.

Course Learning Outcomes:
Upon successful completion of this course students will demonstrate knowledge of:

- Introduction to Statistics, definitions and data classification, types of studies and types of samples.
- Graphical displays of data, frequency distributions, analyzing graphs.
- Numerical descriptions of data, measures of center tendency, measures of dispersion, skewness and kurtosis.
- Correlation and regression.
- Theory of attributes.

Contents:

UNIT I

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

UNIT II

Measures of Central Tendency: mathematical and positional. Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, skewness and kurtosis.

UNIT III

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

UNIT IV

Theory of attributes, consistency of data, independence and association of attributes, measures of association and contingency.

SUGGESTED READINGS:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002). *Fundamentals of Statistics*, 8th Ed. Vol. I & II, The World Press, Kolkata.
2. Miller, I. and Miller, M. (2006). *John E. Freund's Mathematical Statistics with Applications*, 7th Ed., Pearson Education, Asia.
3. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007). *Introduction to the Theory of Statistics,* 3rd Ed., (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

PRACTICAL/ LAB WORK
List of Practicals:

1. Graphical representation of data.
2. Problems based on measures of central tendency.
3. Problems based on measures of dispersion.
4. Problems based on combined mean and variance and coefficient of variation.
5. Problems based on moments, skewness and kurtosis.
6. Fitting of polynomials, exponential curves.
7. Karl Pearson correlation coefficient.
8. Partial and multiple correlations.
9. Spearman rank correlation with and without ties.
10. Correlation coefficient for a bivariate frequency distribution.
11. Lines of regression, angle between lines and estimated values of variables.
12. Checking consistency of data and finding association among attributes.

Week-wise Teaching Plan:

Week 1	Introduction to statistics, development, importance and scope of statistics.
Week 2	Measurement scales and types of data. Practical work.
Week 3	Presentation of data by tables and graphs. Practical work.
Week 4-6	Measures of central tendency, cumulative frequency distributions. Practical work.
Week 6-7	Measures of dispersion. Practical work.
Week 8	Moments. Practical work.
Week 9	Measures of skewness and kurtosis. Practical work.
Week 10	Bivariate data scatter diagram, principle of least squares and curve fitting. Practical work.
Week 11	Pearson's correlation, rank correlation. Practical work.
Week 12	Regression. Practical work.
Week 13	Multiple and partial correlation. Practical work.
Week 14-15	Theory of attributes. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Introduction to Statistics**,** development, importance and scope of statistics, scales of measurements and types of data.	Class room lectures and Practical work.	Participation in class discussion and completion of assignment.
I	Presentation of data by tables and graphs.	Class room lectures and Practical work.	Participation in class discussion and completion of assignment
II	Measures of central tendency, cumulative frequency distributions.	Class room lectures and Practical work.	Participation in class discussion and completion of assignment.
II	Measures of dispersion, moments, measures of skewness and kurtosis.		
A*	Understanding of basic concept of statistics, measures of central tendency, dispersion, moments, skewness and kurtosis.	Class test / Assignment work.	Extent of clarity in theoretical concepts.
III	Bivariate data, scatter diagram, Principle of least squares, curve fitting	Class room lectures and Practical.	Participation in class discussion and completion of assignment.
III	Pearson's correlation, rank correlation, multiple and partial correlation coefficients.		
III	Regression		
IV	Theory of attributes, independence and association of attributes.	Class room lectures and Practical.	Participation in class discussion and completion of assignment.
B*	Understanding the concepts correlation, principle of least square, curve fitting and regression.	Assignment work/ class test.	Extent of clarity in theoretical concepts.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Statistical population and sample, Measures of central tendency, Bivariate data, Regression, Theory of attributes.

Bachelor of Science (Hons.) in Statistics

STAT-GE-2: Introductory Probability

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:

- Understanding probability theory at basic and advance level, random variables and also their convergences at weak and strong levels.
- Different probability distribution (discrete and continuous).

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

- The fundamental concepts of Probability Theory.
- Solving probabilistic problems.
- Understanding random variables and computing properties of distribution they follow.
- Different probability distributions and their implementation at realistic models.

Contents:

UNIT I

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

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

UNIT III

Convergence in probability, almost sure convergence, Chebyshev's inequality, weak law of large numbers, De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T.).

UNIT IV

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, exponential, beta, gamma.

SUGGESTED READINGS:

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

Publishing, New Delhi.

PRACTICAL/LAB WORK
List of Practicals:

1. Fitting of binomial distributions for n and p = q = ½ given.
2. Fitting of binomial distributions for n and p given.
3. Fitting of binomial distributions computing mean and variance.
4. Fitting of Poisson distributions for given value of lambda.
5. Fitting of Poisson distributions after computing mean.
6. Application problems based on binomial distribution.
7. Application problems based on Poisson distribution.
8. Problems based on area property of normal distribution.
9. To find the ordinate for a given area for normal distribution.
10. Application based problems using normal distribution.
11. Fitting of normal distribution when parameters are given.
12. Fitting of normal distribution when parameters are not given.

Week-wise Teaching Plan:

Week 1	Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability – classical, statistical, and axiomatic.
Week 2-3	Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability.
Week 4	Bayes' theorem and its applications.
Week 5-6	Random Variables: Discrete and continuous random variables, pmf, pdf, cdf. Illustrations of random variables and its properties.
Week 7-8	Expectation, variance, moments and moment generating function.
Week 9-10	Convergence in probability, almost sure convergence, Chebyshev's inequality, weak law of large numbers.
Week 11-12	De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T.).
Week 13-14	Discrete probability distributions: Binomial, Poisson, Geometric, Negative-Binomial and Hypergeometric.
Week 15-16	Continuous probability distributions: Uniform, Normal, Exponential, Beta and Gamma.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	**Course Learning Outcomes**	**Teaching and Learning Activity**	**Assessment Tasks**
I	Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability–classical, statistical, and axiomatic.	Class room lectures and discussions.	Participation in class discussion and problem solving.

I	Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability.		
I	Bayes' theorem and its applications.		
II	Random Variables: Discrete and continuous random variables, pmf, pdf, cdf. Illustrations of random variables and its properties.	Class room lectures and discussions.	Participation in class discussion and problem solving.
II	Expectation, variance, moments and moment generating function.		
III	Convergence in probability, almost sure convergence, Chebyshev's inequality, weak law of large numbers.	Class room lectures and discussions.	Participation in class discussion and problem solving.
III	De-Moivre Laplace and Lindeberg-Levy Central Limit Theorem (C.L.T.).		
IV	Discrete probability distributions: Binomial, Poisson, Geometric, Negative Binomial and Hypergeometric.	Class room lectures and discussions.	Participation in class discussion and problem solving.
IV	Continuous probability distributions: Uniform, Normal, Exponential, Beta and Gamma.		

Keywords: Random Variables**,** Discrete and Continuous Probability distributions along with their characteristic properties, Law of Large numbers.

Bachelor of Science (Hons.) in Statistics
STAT-GE-3: Basics of Statistical Inference

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:
- To learn how the mathematical ideas of Statistics carry over into the world of applications.
- To analyse and interpret the data.

Course Learning Outcomes:
After completing this course, students should have developed a clear understanding of:
- Theory of estimation.
- Tests of hypothesis.
- Application of Chi-square test.
- Nonparametric tests.
- Analysis of variance.
- Fundamentals and analysis of basic designs (CRD, RCBD).
- Bioassay.

Contents:

UNIT I

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

UNIT II

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

UNIT III

Tests for the significance of correlation coefficient, Sign test for median, Sign test for symmetry, Wilcoxon two-sample test.

UNIT IV

Analysis of variance, One-way and two-way classification; Brief exposure of three basic principles of design of experiments, treatment, plot and block; Analysis of completely randomized design; Randomized complete block design. Bioassay.

SUGGESTED REDINGS:

1. Bancroft, H. (1962). *Introduction to Bio-Statistics*, P.B. Hoebar, New York.
2. Daniel, Wayne W. (2005). *Bio-statistics: A Foundation for Analysis in the Health Sciences*, John Wiley.
3. Dass, M.N. and Giri, N.C. (1986). *Design and analysis of experiments*, John Wiley.
4. Goldstein, A. (1971). *Biostatistics-An introductory text*, The Macmillion, New York.
5. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): *Fundamentals of statistics,* Vol.-I & II, World Press, Kolkata.
6. Miller, I. and Miller, M. (2014). *Mathematical Statistics with Applications*, Pearson.

PRACTICAL/LAB WORK
List of Practicals:

1. Estimators of population mean.
2. Confidence interval for the parameters of a normal distribution (one sample and two sample problems).
3. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems).
4. Chi-square test of proportions.
5. Chi-square tests of association.
6. Chi-square test of goodness-of-fit.
7. Test for correlation coefficient.
8. Sign test for median.
9. Sign test for symmetry.
10. Wilcoxon two-sample test.
11. Analysis of Variance of a one way classified data
12. Analysis of Variance of a two way classified data.
13. Analysis of a CRD.
14. Analysis of an RBD.

Week-wise Teaching Plan:

Week 1-2	Estimation of population mean, confidence intervals for the parameters of a normal distribution (one sample and two sample problems). Practical work.
Week 3-5	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 sample and two sample problems). Practical work.
Week 6-7	Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chi-square Test, Yates' correction. Practical work.
Week 8-9	Tests for the significance of correlation coefficient, Sign test for median, Sign test for symmetry, Wilcoxon two-sample test. Practical work.
Week 10-11	Analysis of variance, One-way and two-way classification. Practical work.
Week 12	Brief exposure of three basic principles of design of experiments, treatment, plot and block.
Week 13	Completely randomized design (CRD). Practical work.
Week 14	Randomized complete block design (RCBD). Practical work.
Week 15	Bioassay.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Problems of estimation.	Class room lectures and discussions. Practical Work.	Participation in class and discussion.
I	Hypothesis testing.	Class room lectures and discussions. Practical Work.	Participation in class and discussion.
A*	Understanding of estimation and hypothesis testing.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
II	Applications of Chi-square test.	Class room lectures and discussions. Practical Work.	Participation in class and discussion.
III	Non-parametric tests.		
B*	Understanding of Chi-square test and Nonparametric tests.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.
IV	Analysis of variance, Fundamental concepts of Design of Experiments.	Class room lectures and discussions. Practical Work.	Participation in class and discussion.
IV	Completely randomized design (CRD), Randomized complete block design (RCBD), Bioassay.	Class room lectures and discussions. Practical Work.	Participation in class and discussion.
C*	Understanding of Analysis of variance; fundamentals and analysis of basic designs (CRD, RCBD), Bioassay.	Class Test/ Assignment work.	Extent of clarity in theoretical concepts.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Problems of estimation, Test of significance, Categorical data, Completely randomized design , Randomized complete block design **,** Nonparametric tests.

Bachelor of Science (Hons.) in Statistics
STAT-GE-4: Applied Statistics

Credits: 6 **Marks: 150**

Course Objectives:
The learning objectives include:

- This course will help students to know the applications of Statistics and learn and apply these techniques in the core course of their study.
- This course will give exposure to four applied fields of statistics viz. Time Series, Index Numbers, Statistical Quality Control and Demographic methods.
- They will be having hands on practice of working on the data related to above mentioned fields.

Course Learning Outcomes:
After completing this course, students should have developed an understanding of:

- Time series data, components of time series data, study the behavior and identifying the variation due to different components in the data.
- They will study to identify and measure various components of time series data.
- The fundamental concepts of Index Numbers, Construction of price and quantity Index numbers.
- Construction of Wholesale and Consumer price Index and its significance.
- Statistical Quality Control, Use of Statistical methods in industrial research and practice.
- Chance and Assignable causes of variation in data.
- Statistical process control tools- Control charts for variables and attributes.
- To learn about different demographic methods. Measurement of mortality and fertility rates, reproduction and population growth measures.
- Construction and importance of Life Table.

Contents:

UNIT I

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

UNIT II

Index numbers: Introduction, Construction of price and quantity Index Numbers by Simple and Weighted Aggregate Method. Construction of price and quantity index numbers by Laspeyre's, Paasche's, Marshall-Edgeworth's and Fisher's Formula. Criteria for a good

index number. Construction of wholesale price index number, fixed base index number and Consumer price indexnumber with interpretation. Uses and limitations of index numbers.

UNIT III

Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: Chance and Assignable. 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

Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR.

SUGGESTED READINGS:

1. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008). *Fundamentals of Statistics*, Vol. II, 9th Ed., World Press, Kolkata.
2. Gupta, S.C. and Kapoor, V.K. (2014). *Fundamentals of Mathematical Statistics*, 11th Ed., Sultan Chand.
3. Mukhopadhyay, P. (1999). *Applied Statistics*, New Central Book Agency, Calcutta.
4. Montogomery, D.C. (2009). *Introduction to Statistical Quality Control*, 6th ed., Wiley India Pvt. Ltd.

PRACTICAL/LAB WORK
List of Practicals:

1. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and plotting of trend values and comparing with given data graphically.
2. Measurement of seasonal indices by Ratio-to-trend method and plotting of trend values and comparing with given data graphically.
3. Construction of price and quantity index numbers by Laspeyre's formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula. Comparison and interpretation.
4. Construction of wholesale price index number, fixed base index number and consumer price index number with interpretation.
5. Construction and interpretation of $\bar{X}$ and R-chart.
6. Construction and interpretation p-chart (fixed sample size) and c-chart.
7. Computation of measures of mortality.
8. Completion of life table.
9. Computation of measures of fertility and population growth.

Week-wise Teaching Plan:

Week 1-2	Introduction to Time Series, Components of time series, Decomposition of time series-Additive and multiplicative model with their merits and demerits.
Week 2-3	Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages. Method of least squares (Linear trend). Practical work.
Week 3-4	Measurement of trend by method of least squares (quadratic and exponential). Measurement of seasonal variations by method of ratio to trend. Practical work.
Week 5-6	Introduction to Index Numbers, Construction of price and quantity Index Numbers by Simple Aggregate Method and Weighted Aggregate Method, Comparison and interpretation. Practical work.
Week 7	Criteria of a good Index number. Construction of wholesale price index numbers, fixed base index numbers and consumer price index numbers with interpretation. Uses and limitations of index numbers. Practical work.
Week 8	Introduction to Statistical Quality Control, Use of Statistical methods in industrial research and practice. Causes of variations in quality: chance and Assignable with illustrations.
Week 9	General theory of control charts, process & product control Determination of tolerance limits. Practical work.
Week 10	Control charts for variables: X- bar and R-charts. Illustrations and Practical work.
Week 11	Control charts for attributes: p and c-charts Illustrations and Practical work.
Week 12	Introduction to Demographic Methods, measurement of population, rates and ratios of vital events.
Week 13	Measurement of mortality: Crude Death Rate, Specific Death Rate (w.r.t. Age and sex), Infant Mortality Rate, Standardized death rates. Practical work.
Week 14	Life (mortality) tables: Assumptions, Description and Construction of Life table. Uses of Life table. Practical work.
Week 15	Measurement of fertility and reproduction rate: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR. Comparison and Interpretation. Practical work.

Facilitating the Achievement of Course Learning Outcomes:

Unit No.	Course Learning Outcomes	Teaching and Learning Activity	Assessment Tasks
I	Time series data, components of time series data, study the behavior and identifying the variation due to different components in the data.	(i) Class room lectures and discussions.	Participation in class discussion.
I	Identify and measure various components of time series data.	(i)Class room lectures and discussions. (ii) Practical problems from	Participation in class discussion. Problem solving, Analyse and Interpret the results.

		the list of practical.	
II	Index Numbers, construction of price and quantity index numbers.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
II	Construction of wholesale and Consumer price Index and its significance.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
A*	Understanding basic concepts with relevance and importance of time series and index numbers.	Class Test/ Assignment work.	Extent of clarity of theoretical concepts studied in the course.
III	Statistical Quality Control, Use of Statistical methods in industrial research and practice. Chance and Assignable causes of variation in data.	(i) Class room lectures and discussions.	Participation in class discussion.
III	Statistical process control tools- Control charts for variables, attributes.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
IV	Different demographic methods. Measurement of mortality and fertility rates, reproduction and population growth measures.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
IV	Construction and importance of Life Table.	(i) Class room lectures and discussions. (ii) Practical problems from the list of practical.	Participation in class discussion. Problem solving, Analyse and Interpret the results.
B*	Understanding of complete	Class Test/	Extent of clarity of theoretical

	course.	Assignment work	concepts studied in the course.
C*	Application of Time Series, Index Numbers, Statistical Quality Control and Demographic Methods. (optional)	Project Work and its presentation.	Ability to apply concepts of Time Series, Index Numbers, Statistical Quality Control and Demographic Methods on practical data, understanding and giving solutions to a problem.

*As per requirements of Internal Assessment for B.Sc. (Hons.).

Keywords: Components and Decomposition of time series, Index Numbers, Control charts, Demographic Methods, Measurement of mortality, Life Table.

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