

**KURUKSHETRA UNIVERSITY, KURUKSHETRA**  
**(Established by the State Legislature Act XII of 1956)**  
**(‘A+’ Grade, NAAC Accredited)**



Scheme of Examination and Syllabus of  
B.Sc. with Statistics CBCS LOCF w.e.f. session 2020-21 in Phased manner

CBCS CURRICULUM (2020-21)

Program Name: B.Sc. with Statistics CBCS LOCF

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**Credit Distribution for Statistics subject in the programme B.Sc. with Statistics under Choice Based Credit System (CBCS LOCF) w.e.f. the session 2020-21.**

	Core Courses (DSC)	Ability Enhancement Courses	Discipline Specific Elective Courses(DSE)	Skill Enhancement Courses(SEC)	Total Credits
Theory	24	-	08	4	32
Practical	08	-	04	-	12
Total	32	-	12	4	48

**Semester wise Distribution of Credits**

	First year Credit		Second year Credit		Third year Credit		Total Credits
	1 <sup>st</sup> Sem	2 <sup>nd</sup> Sem	3 <sup>rd</sup> Sem	4 <sup>th</sup> Sem	5 <sup>th</sup> Sem	6 <sup>th</sup> Sem	
Ability Enhancement Courses (AECC)	-	-			-	-	-
Core Courses	08	08	08	08	-	-	32
Discipline Specific Elective Courses(DSC)	-	-	-	-	06	06	12
Skill Enhancement Courses(SEC)	-	-	2	-	-	2	4
Total	08	08	10	08	06	08	48

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**Scheme of Examination of B. Sc with Statistics under CBCS w.e.f. 2020-2021 in phased manner**

<b>Semester-I</b>								
Paper Code	Course opted	Nomenclature	Credits	Hours/ week	Marks (B.Sc.)			Duration of Exam (hours)
					Ext.	Int	Total	
DSCS-118	Statistics-I	Statistical Method-I	3	3	60	15	75	Three
DSCS-119	Statistics-II	Probability Theory	3	3	60	15	75	Three
DSCS-120	Statistics Practical-I	Practical-I	2	4	40	10	50	Three
<b>Semester-II</b>								
DSCS-218	Statistics-III	Statistical Method-II	3	3	60	15	75	Three
DSCS-219	Statistics-IV	Probability Distributions	3	3	60	15	75	Three
DSCS-220	Statistics Practical-II	Practical-II	2	2	40	10	50	Three
<b>Semester-III</b>								
SEC-301	Skill Enhancement Course-I	Programming Skills With C	2	2	40	10	50	Three
DSCS-318	Statistics-V	Elementary Inference	3	3	60	15	75	Three
DSCS-319	Statistics-VI	Sample Surveys	3	3	60	15	75	Three
DSCS-320	Statistics Practical-III	Practical-III	2	4	40	10	50	Three
<b>Semester-IV</b>								
DSCS-418	Statistics-VII	Parametric and Non-parametric Tests	3	3	60	15	75	Three
DSCS-419	Statistics-VIII	Design of Experiments	3	3	60	15	75	Three
DSCS-420	Statistics Practical-IV	Practical-IV	2	4	40	10	50	Three
<b>Semester-V</b>								
DSES1-518	Statistics Elective-1	Applied Statistics-1	2	2	40	10	50	Three
DSES2-518		Bio-Statistics						
DSES3-519	Statistics Elective-II	Numerical Methods and Fundamentals of Computers	2	2	40	10	50	Three
DSES4-519		Econometrics						
DSES-520	Statistics Practical-V	Practical-V	2	4	40	10	50	Three

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Semester-VI								
SECS1-601	Skill Enhancement Course-IV (Statistics)	Statistical Data Analysis using R	2	2	40	10	50	Three
SECS2-601		Statistical Simulation						
DSES5-618	Statistics Elective-III	Applied Statistical-II	2	2	40	10	50	Three
DSES6-618		Linear Models						
DSES7-619	Statistics Elective-IV	Operations Research	2	2	40	10	50	Three
DSES8-619		Actuarial Statistics						
DSES-620	Statistics Practical- VI	Practical-VI	2	4	40	10	50	Three

**Note:-**The course (paper) SECS1-601 or SECS2-601 Skill Enhancement Course IV (Statistics) of the Programme B.Sc. Physical Sciences: (Physics, Mathematics, Statistics), which will be offered in the 6<sup>th</sup> Semester of the Programme, is same as the course SECS1-401 or SECS2-402 Skill Enhancement Course II (Statistics) of the Programme B.Sc. Physical Sciences: (Statistics, Mathematics, Computer Science) which will be offered in the 4<sup>th</sup> semester of that Programme. So, the paper with two different codes (SECS1-601/ SECS1-401) but having exactly same syllabus can be taught simultaneously and only one question paper by printing both the codes SECS1-601/ SECS1-401 will be set. Similarly, one question paper by printing both the codes SECS2-601/ SECS2-401 will be set.

**Program Outcomes (PO) for Under Graduate Programmes (CBCS) in the Faculty of Sciences, Kurukshetra University, Kurukshetra**

<b>PO1</b>	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge gained during course of study
<b>PO2</b>	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large
<b>PO3</b>	Problem Solving	Capability of applying knowledge to solve scientific and other problems
<b>PO4</b>	Individual and Team Work	Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.
<b>PO5</b>	Investigation of Problems	Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions
<b>PO6</b>	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices
<b>PO7</b>	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices
<b>PO8</b>	Life-Long Learning	Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout the life
<b>PO9</b>	Environment and Sustainability	Ability to design and develop modern systems which are environmentally sensitive and to understand the importance of sustainable development.
<b>PO10</b>	Ethics	Apply ethical principles and professional responsibilities in scientific practices
<b>PO11</b>	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects

**PSO for Under Graduate CBCS LOCF Programme in the  
subject of Statistics**

1. The programme is designed to equip students with all the major concepts of Statistics along with the tools required to implement them.
2. Having practical Component with every course invokes their exploratory side and fine tunes the interpretation abilities.
3. The structure of the programme motivates the students to pursue Careers in public & private sectors.

**Course Objectives:**

The learning objectives include:

Introduction to Statistics, different measurement scales, various types of data, to analyze and interpret data, 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, dispersion, skewness, kurtosis and should be able to compute them as well, understanding the concept of moments and attributes.

**Course Outcomes:**

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

- Fundamental concepts of statistics.
- Tabular and graphical representation of data based on variables.
- Measures of central tendency, measures of Dispersion, Skewness and Kurtosis, Moments and their use in studying various characteristics of data.
- Theory of attributes: conditions for the consistency and criteria for the independence of data for attributes.

## **B.Sc.-I Semester-I**

**DSCS-118**  
Time: 3 Hours

**Statistical Methods-I**

**Credits: 3**  
M.M.: 60+15\*  
\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

**Introduction of Statistics:** Origin, development, definition, scope, uses and limitations.

**Types of Data:** Qualitative and quantitative data, nominal and ordinal data, time series data, discrete and continuous data, frequency and non-frequency data.

**Collection and Scrutiny of Data:** Collection of primary and secondary data- its major sources including some government publications, scrutiny of data for internal consistency and detection of errors of recording, classification and tabulation of data.

### **UNIT-II**

**Presentation of Data:** Frequency distribution and cumulative frequency distribution, diagrammatic and graphical presentation of data, construction of bar, pie diagrams, histograms, frequency polygon, frequency curve and ogives.

**Measures of Central Tendency and Location:** Arithmetic mean, median, mode, geometric mean, harmonic mean; partition values-quartiles, deciles, percentiles and their graphical location along with their properties, applications, merits and demerits.

### **UNIT-III**

**Measures of Dispersion:** Concept of dispersion, characteristics for an ideal measure of dispersion. Absolute and relative measures based on: range, inter quartile range, quartile deviation, coefficient of quartile deviation, Mean deviation, coefficient of mean deviation, variance, standard deviation ( $\sigma$ ), coefficient of variation and properties of these measures, root mean square deviation and their relationship, variance of the combined series.

**Moments:** Moments about mean and about any point and derivation of their relationships, effect of change of origin and scale on moments, Sheppard's correction for moments (without derivation), Charlier's checks; Pearson's  $\beta$  and  $\gamma$  coefficients.

### **UNIT-IV**

**Skewness and Kurtosis:** Coefficients of Skewness and Kurtosis with their interpretations.

**Theory of Attributes:** Symbolic notations, dichotomy of data, class frequencies, order of class frequencies, consistency of data, independence and association of attributes, Yule's coefficient of association and coefficient of colligation and their relationship.



**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Fundamental of Statistics Vol.I	Goon A.M., Gupta M.K., Dasgupta B.	World Press, Calcutta, (2016)
2.	Statistics	Johnson R.	Wiley Publishers (1995)
3.	Basic Statistics International	Aggarwal B.L.	New Age (2013)
4.	Fundamentals of Mathematical Statistics	Gupta S.C.& Kapoor V.K.	Sultan Chand & Sons (2014)
5.	Programmed Statistics	Aggarwal B.L.	New Age International (2017)

## **B.Sc.-I Semester-I**

**DSCS-119**

### **Probability Theory**

#### **Course Objectives:**

To understand the concepts of probability, its applications, the concept of random variables, probability functions, expectation and generating functions, properties of random variables like expectation, moment generating function, cumulative generating function etc. , introduction to p.m.f, p.d.f and c.d.f.

#### **Course Outcomes:**

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

- The fundamental concepts of Probability Theory, solving probabilistic problems.
- Random variables and its probability functions, joint, marginal and conditional probability distribution.
- Concept of expectation for the random variables with their distributions and properties.
- Moment generating function, cumulant generating function and characteristic function.

## **B.Sc.-I Semester-I**

**DSCS-119**  
Time: 3 Hours

### **Probability Theory**

**Credits: 3**  
M.M.: 60+15\*  
\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

#### **UNIT-I**

**Concepts in Probability:** Random experiment, trial, sample point, sample space, operation of events, exhaustive, equally likely, mutually exclusive and independent events; Definition of probability-classical, relative frequency, statistical and axiomatic approach.

#### **UNIT-II**

Conditional probability. Addition and multiplication laws of probability and their extension to  $n$  events. Boole's inequality; Baye's theorem and its applications.

#### **UNIT-III**

**Random Variable and Probability Functions:** Definition of random variable, discrete and continuous random variable, probability function, probability mass function and probability density functions, distribution function and its properties, functions of random variables, joint, marginal and conditional probability distribution function.

#### **UNIT-IV**

**Mathematical Expectation:** Definition and its properties-moments, addition and multiplication theorem of expectation. Conditional expectation and conditional variance.

**Generating Functions:** Moments generating function, cumulant generating function, probability generating function along with their properties. Characteristic function.

**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Fundamentals of Mathematical Statistics	Gupta S.C.& Kapoor V.K.	Sultan Chand & Sons (2014)
2.	Elementary Probability	David S.	Oxford Press (2003)
3.	Introduction to Mathematical Statistics	Hoel P.G.	Asia Pub. House (2018)
4.	New Mathematical Statistics	BansiLal& Arora S.	Satya Prakashan
5.	Introduction to Mathematical Statistics	Kapoor & Sexena.	S.Chand (1960)

## **B.Sc.-I Semester-I**

**DSCS-120**

**Practical-I**

### **Course Objectives:**

The learning objectives include:

To motivate students towards intrinsic interest in statistical thinking, to represent, analyze and interpret data, also to understand the concept of attributes.

### **Course Outcomes:**

On completion of this course students will be able to:

1. Tabulate and represent the data graphically.
2. Compute different measures of central tendency, Dispersion, Skewness and Kurtosis along with their interpretation.
3. Compute moments and their use in studying various characteristics of data
4. Find association for qualitative data.

**B.Sc.-I Semester- I**

**DSCS-120**  
Time: 3 Hours

**Practical-I**

**Credit: 2**  
M.M.: 40+10\*  
\*Internal Assessment

**Note: Five questions will be set. The candidate will be required to attempt any three.**

1. To construct frequency distributions using exclusive and inclusive methods
2. Representation of data using Bar and pie diagrams
3. Representation of data using Histogram, Frequency Polygon, Frequency Curve and Ogives.
4. To compute various measures of central tendency and dispersion.
5. To obtain first four moments for the given grouped frequency distribution.
6. To apply Charlier's checks while computing the moments for a given frequency distribution.
7. To obtain moments applying Sheppard's correction.
8. To obtain various coefficients of skewness and kurtosis.
9. To toss a coin at least 100 times and plot a graph of heads with respect to number of tosses.
10. To discuss the association of attributes for a 2x2 contingency table using Yule's coefficient of association and colligation.

## **B.Sc.-I Semester-II**

**DSCS-218**

**Statistical Methods-II**

### **Course Objectives:**

The learning objectives include:

To understand and compute various statistical measures of correlation, fitting of curve and regression.

### **Course Outcomes:**

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

- Correlation, its properties and its implementation in real life problems.
- Principle of least square, curve fitting of different curves.
- Linear Regression analysis, its properties and its implementation in real life problems.
- Multivariate Regression analysis, its properties and multiple correlation.

## **B.Sc.-I Semester-II**

**DSCS-218**

Time: 3 Hours

**Statistical Methods-II**

**Credits: 3**

M.M.: 60+15\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

**Correlation:** Concept and types of correlation, methods of finding correlation - scatter diagram, Karl Pearson's Coefficient of correlation ( $r$ ), its properties, coefficient of correlation for a bivariate frequency distribution. Rank correlation with its derivation, its merits and demerits, limits of rank correlation coefficient, tied or repeated ranks.

### **UNIT-II**

**Curve Fitting:** Principle of least squares, fitting of straight line, second degree parabola, power curves of the type  $Y=aX^b$ , exponential curves of the types  $Y=ab^X$  and  $Y=ae^{bX}$ .

### **UNIT-III**

**Linear Regression:** Two lines of regression, regression coefficients, properties of regression coefficients, angle between two regression lines, standard error of estimate obtained from regression line, correlation coefficient between observed and estimated values, distinction between correlation and regression.

### **UNIT-IV**

**Multivariate Data:** Plane of regression, properties of residuals, variance of the residual. Multiple and partial correlation for three variables: coefficient of multiple correlation and its properties, coefficient of partial correlation and its properties, multiple correlation in terms of total and partial correlations and coefficient of determination.



**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Introduction to Theory of Statistics	Mood A.M., Graybill F.A. & Boes D.C.	McGraw Hill (2017)
2.	Applied General Statistics	Croxton F.E., Cowden D.J. & Kelin S.	Prentice Hall (1968)
3.	Introduction to Mathematical Statistics	Kapoor & Sexena.	S.Chand (1960)
4.	Statistical Methods	Snedecor G.W. & Cochran W.G.	Iowa State Uni. Press (2014)
5.	Fundamentals of Mathematical Statistics	Gupta S.C. & Kapoor V.K.	Sultan Chand & Sons (2014)

## **B.Sc.-I Semester-II**

**DSCS-219**

### **Probability Distributions**

#### **Course Objectives:**

The learning objectives include:

Explaining different probability distributions (discrete and continuous) with their properties and applications

#### **Course Outcomes:**

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

- Discrete and continuous distributions.
- Some important discrete probability distributions, with their characteristics, and their implementation at realistic models.
- Some important continuous probability distributions, with their characteristics, and their implementation at realistic models
- Normal distribution, its derivation and different characteristics.

## **B.Sc.-I Semester-II**

**DSCS-219**

Time: 3 Hours

**Probability Distributions**

**Credits: 3**

M.M.: 60+15\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

Bernoulli distribution and its moments, Binomial distribution: Moments, recurrence relation for the moments, mean deviation about mean, mode, moment generating function (m.g.f), characteristic function, additive property and recurrence relation for the probabilities of Binomial distribution.

### **UNIT-II**

Poisson distribution: Poisson distribution as a limiting case of Binomial distribution, moments, mode, recurrence relation for moments, m.g.f., additive property of independent Poisson variates. Negative Binomial distribution: m.g.f., deduction of moments of negative binomial distribution from those of binomial distribution. Geometric distribution: moments, m.g.f, and lack of memory.

### **UNIT-III**

Continuous uniform distribution: Moments, m.g.f., characteristic function and mean deviation. Gamma distribution: m.g.f., and additive property. Exponential distribution: m.g.f., moments and lack of memory.

### **UNIT-IV**

Normal distribution as a limiting form of binomial distribution, chief characteristics of Normal distribution; mode, median, m.g.f. and moments of Normal Distribution, A linear combination of independent normal variates, points of inflexion, mean deviation about mean, area property of Normal distribution, importance and fitting of normal distribution.

**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Statistics: A Beginner's Text Vol. II	Bhat B.R., Srivenkatramana T. & RaoMadhava K.S.	New Age International
2.	Fundamentals of Mathematical Statistics	Gupta S.C. & Kapoor V.K.	Sultan chand & Sons (2014)
3.	Introduction to Mathematical Statistics	Kapoor & Sexena.	S.Chand (1960)
4.	Statistics	Johnson R. Publishers	Wiley (1995)
5.	Mathematical Statistics With Applications	Freund's J.E.	Prentice Hall (2013)

## **B.Sc.-I Semester-II**

**DSCS-220**

**Practical-II**

### **Course Objectives:**

The learning objectives include:

To understand the concepts of correlation, regression, probability distributions along with their applicability in real-life situations.

### **Course Outcomes:**

On completion of this course students will be able to:

1. Calculate various coefficients of correlation.
2. Find line and curve of best fit for given observations.
3. Estimate unknown values from known values through regression equations.
4. Fit different probability distributions such as binomial, Poisson and normal distributions

**B.Sc.-I Semester- II**

**DSCS-220**  
Time: 3 Hours

**Practical-II**

**Credit: 2**  
M.M.: 40+10\*  
\*Internal Assessment

**Note: Five questions will be set. The candidate will be required to attempt any three.**

1. To compute Karl Pearson's coefficient of correlation for given bivariate frequency distribution.
2. To find Spearman's rank correlation coefficient for given data.
3. To fit the straight line for the given data on pairs of observations.
4. To fit the second degree curve for the given data.
5. To fit the curve of the type  $Y=aX^b$  for the given data on pairs of observations.
6. To obtain the regression lines for given data.
7. To compute partial and multiple correlation coefficients for the given tri-variate data.
8. To obtain plain of regression for the given tri - variate data.
9. To fit binomial distribution to given data.
10. To fit Poisson distribution to given data.
11. To fit normal distribution to given distribution using area under the normal curve
12. To fit normal distribution to given distribution using method of ordinates

## **B.Sc.-II Semester-III**

**DSCS-318**

### **Elementary Inference**

#### **Course Objectives:**

The learning objectives include:

Explaining the concept of statistical Estimation and drawing inference about the unknown population parameters based on random samples, validating our estimation/ inference about the population using hypothesis testing, concept of Testing of hypothesis and estimation theory, concept of large sample tests.

#### **Course Outcomes:**

After completing this course, students will possess skills concerning:

- Introduction to estimation and basic terminologies; parameter, statistic, standard error, sampling distribution of a statistic, characteristics of a good estimator etc.
- Different methods of estimation, estimation of parameters for some distributions.
- Testing of Hypotheses and related terms.
- Large sample tests, determination of confidence interval.

**B.Sc.-II Semester-III**

**DSCS-318**

Time: 3 Hours

**Elementary Inference**

**Credits: 3**

M.M.: 60+15\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

**UNIT-I**

**Statistical Estimation:** Parameter and statistic, Basic concept of sampling distribution. Point and interval estimate of a parameter, concept of bias and standard error of an estimate. Standard errors of sample mean, sample proportion, standard deviation, Properties of a good estimator: Unbiasedness, Efficiency, Consistency and Sufficiency (definition and illustrations).

**UNIT-II**

**Methods of Estimation:** Method of moments, method of maximum likelihood and its properties (without proof). Estimation of parameters of Binomial, Poisson and Normal distributions

**UNIT-III**

**Testing of Hypotheses:** Statistical Hypothesis:- Simple and composite, test of statistical hypothesis, Null and alternative hypotheses, critical region, types of errors, level of significance, power of a test, one tailed and two tailed testing, p-value, BCR, most powerful test, Neyman-Pearson Lemma, Test of simple hypothesis against a simple alternative in case of Binomial and Normal distributions.

**UNIT-IV**

**Large Sample Tests:** Testing of a single mean, single proportion, difference of two means, two standard deviations and two proportions. Fisher's Z transformation. Determination of confidence interval for mean, variance and proportion.



**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	A First Course on Parametric Inference	Kale B.K.	Narosa (2005)
2.	Introduction to Theory of Statistics	Mood A.M., Graybill F.A. & Boes D.C.	McGraw Hill (2017)
3.	Mathematical Statistics With Applications	Freund's J.E.	Prentice Hall (2013)
4.	Fundamentals of Mathematical Statistics	Gupta S.C. & Kapoor V.K.	Sultan chand & Sons (2014)

## **B.Sc.-II Semester-III**

**DSCS-319**

### **Sample Surveys**

#### **Course Objectives:**

The learning objectives include:

Explaining the concept of sample surveys, its need, objectives and different sampling techniques.

#### **Course Outcomes:**

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

- The basic concept of sample survey and its need.
- Simple random sampling along with its practical applicability
- Stratified random sampling along with its practical applicability
- Systematic sampling along with its practical applicability

**B.Sc.-II Semester-III**

**DSCS-319**  
Time: 3 Hours

**Sample Surveys**

**Credits: 3**  
M.M.: 60+15\*  
\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

**UNIT-I**

Concepts of census and sample survey, basic concepts in sampling. Sampling and Non-sampling errors. Principal steps involved in a sample survey; bias, precision and accuracy, advantages of sampling over complete census, limitations of sampling, different methods of data collection.

**UNIT-II**

**Basic sampling methods:** Simple random sampling (SRS) with and without replacement, use of random number tables, estimation of mean and variance in case of SRS. Simple random sampling of attributes, size of simple random sample.

**UNIT-III**

Stratified random sampling, estimation of population mean, variance of the estimate of population mean in stratified random sampling, allocation of sample size, proportional allocation, optimum allocation. Comparison of Stratified random sampling with SRS.

**UNIT-IV**

Systematic random sampling, estimation of mean and variance. Comparison of Systematic random sampling with SRS and Stratified random sampling, Ratio and regression methods of estimation under SRSWOR.

**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Sampling Techniques	Cochran W.G.	Wiley Publishers (2007)
2.	Sampling Theory	Des Raj and Chandok	Narosa (2013)
3	Sample Theory of Surveys with Applications	Sukhatmeet. all	Iowa State Uni. Press & IARS (1984)
4.	Fundamentals of Applied Statistics	Gupta S.C.& Kapoor V.K.	Sultan Chand & Sons (2014)
5.	Sampling Techniques	Daroga Singh & Chaudhry, F.S	New age International (2020)

## **B.Sc.-II Semester-III**

**DSCS-320**

**Practical-III**

### **Course Objectives:**

The learning objectives include:

Concept of large sample tests, to understand the process of hypothesis testing, identifying the test for a given problem, recognizing the types of sampling available and using them practically.

### **Course Outcomes:**

On completion of this course students will be able to:

1. Frame null and alternative hypothesis for given problems, performing the right test and finally interpreting them.
2. Evaluate confidence interval.
3. Perform different types sampling procedures, evaluate standard error of estimates.
4. Compare these estimates and to find the gain in precision.

## B.Sc.-II Semester-III

**DSCS-320**

Time: 3 Hours

**Practical-III**

**Credit: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note: Five questions will be set. The candidate will be required to attempt any three.**

1. To apply large sample test of significance for single proportion and difference of two proportions and obtained their confidence intervals.
2. To apply large sample test of significance for single mean and to obtained confidence interval.
3. To apply large sample test of significance for difference between two means and standard deviations.
4. To find standard error of estimate of population mean in case of SRSWR & SRSWOR and comparison of these estimates.
5. To find standard error of estimate of population mean in case of stratified random sampling.
6. To find standard error of estimate of population mean in case of systematic sampling.
7. To select a SRS with and without replacement 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. For SRSWOR, estimate mean, standard error, the sample size
8. Stratified Sampling: allocation of sample to strata by proportional and Neyman's Methods. Compare the efficiencies of above two methods relative to SRS. Estimation of gain in precision in stratified sampling.

## **B. Sc-II Semester-IV**

**DSCS-418**

### **Parametric and Non-parametric Tests**

#### **Course Objectives:**

The learning objectives include:

To understand the concept of Chi-Square distribution, its measures, test for goodness of fit, test of independence of attributes in a contingency table, Sampling Distributions; Student's-t & Snedecor's-F Statistics, their derivations and various measures, applications i.e. testing of hypothesis based on 't' & 'F', and Non-Parametric Tests with their applications.

#### **Course Outcomes:**

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

- Chi-Square distribution with derivation and its application
- Parametric and Non-Parametric Tests, their differences and their field of applicability
- Sampling distributions; Student's 't' and Snedecor's 'F' statistics
- Setting of hypothesis, testing of hypothesis for both Parametric and Non-Parametric tests.

## B.Sc.-II Semester-IV

**DSCS-418**

Time: 3Hours

**Parametric and Non-parametric Tests**

**Credits: 3**

M.M.: 60+15\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

**Chi-square distribution:** Definition, derivation, moment generating function, cumulant generating function, mean, mode, skewness, additive property, conditions for the validity, chi-square test for goodness of fit. Contingency table, coefficient of contingency, test of independence of attributes in a contingency table.

### **UNIT-II**

**Student's 't' and Snedecor's 'F' statistics:** Definition and derivation of Student's 't', constants of t-distribution, limiting form of t-distribution. Definition & derivation of Snedcor's F-distribution, constants of F-distribution, mode of F-distribution. Relationship between t, f and chi-square distribution.

### **UNIT-III**

Testing for the mean and variance of univariate normal distribution, testing of equality of two means and testing of equality of two variances of two univariate normal distributions. Testing for the significance of sample correlation coefficient and **regression coefficient** in sampling from bivariate normal distribution.

### **UNIT-IV**

**Nonparametric Tests:** Concept of non-parametric tests, advantages of non-parametric test over parametric test, Definition of order statistics. Sign test for univariate and bivariate distribution, run test, median test, Kolmogorov-Smirnov one sample test, Kolmogorov-Smirnov two sample test, Mann Whitney U-test (only applications without derivation).



### **Books recommended**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Fundamentals of Statistics, Vol.I	Goon A.M., Gupta M.K. & Dasgupta B.	World Press Calcutta (2016)
2.	Random Variable and Probability Distribution	Cramer H.	Cambridge Uni. Press (2004)
3.	Fundamentals of Mathematical Statistics	Gupta S.C. & Kapoor V.K.	Sultan Chand & Sons (2014)
4.	Practical Nonparametric	W.J. Conover	Wiley Publisher (2006)

## **B.Sc.-II Semester-IV**

**DSCS-419**

**Design of Experiments**

### **Course Objectives:**

The learning objectives include:

To design and conduct experiments and to analyze and interpret the result.

### **Course Outcomes:**

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

- Analysis of variance for both one-way and two-way classifications.
- The fundamental concepts of design of experiments.
- Completely randomized design & Randomized block design.
- Latin square design & Fractional factorial designs with two levels.

**B.Sc.-II Semester-IV**

**DSCS-419**  
Time: 3 Hours

**Design of Experiments**

**Credits: 3**  
M.M.:60+15\*  
\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

**UNIT-I**

**Analysis of variance (ANOVA):** Definition and assumptions for ANOVA. Analysis of variance for one-way classification and two-way classifications for fixed effect models with one observation per cell.

**UNIT-II**

Introduction to design of experiments, terminology: experiment, treatment, experimental unit, blocks, experimental error, replication, precision, efficiency of a design, need for design of experiments, size and shape of plots and blocks. Fundamental principles of design: randomization, replication and local control.

**UNIT-III**

Completely randomized design (CRD), Randomized Block Design (RBD), their layout, statistical analysis, applications, advantages and disadvantages. Efficiency of RBD relative to CRD.

**UNIT-IV**

Latin square design (LSD): Layout, statistical analysis, applications, merits and de-merits of LSD. Factorial designs: Definition, advantages and disadvantages, concept of mean effects and interaction in  $2^2$  design.

**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Design and Analysis Of Experiments	Das M.N. &Giri	Springer Verlage (1987)
2.	Linear Models	Searle S.R.	John Wiley & Sons (2014)
3.	Linear Estimation And Design of Experiments	Joshi D.D.	Wiley Eastern (2020)
4.	Fundamentals of Applied Statistics	Gupta S.C. & Kapoor V.K.	Sultan Chand & Sons (2014)

## **B.Sc.-II Semester-IV**

**DSCS-420**

**Practical-IV**

### **Course Objectives:**

The learning objectives include:

Sampling distribution, test based on them, different non-parametric tests and using them practically. Different designs of experiment, and their implementation.

### **Course Outcomes:**

On completion of this course students will be able to:

1. Perform small sample test and evaluate confidence intervals.
2. Apply Chi-Square test for a given population distribution, goodness of fit.
3. Apply other non-parametric tests and recognizing situations where they are to be used.
4. Perform ANOVA for different designs.

**B.Sc.-II Semester-IV**

**DSCS-420**  
Time: 3 Hours

**Practical-IV**

**Credit: 2**  
M.M.: 40+10\*  
\*Internal Assessment

**Note: Five questions will be set. The candidate will be required to attempt any three.**

1. To apply t -test for testing single mean and difference between means and to obtain their confidence intervals.
2. To apply paired t-test for difference between two means.
3. To apply Chi- square test for goodness of fit.
4. To apply Chi- square test for independence of attributes.
5. To apply test of significance of sample correlation coefficient.
6. To apply F-test for testing difference of two variances.
7. To apply sign test for given data.
8. To apply Run test for given data.
9. To apply Median test for given data.
10. To apply Mann Whitney U-test for given data.
11. Analysis of Variance of a one way classified data
12. Analysis of Variance of a two way classified data with one observation per cell
13. To perform ANOVA in case of CRD and test whether the treatments/ varieties are equally effective.
14. To perform ANOVA for an RBD.
15. To perform ANOVA for an LSD.

## **B.Sc.-III Semester-V**

**DSES1-518**

### **Applied Statistics-I**

#### **Course Objectives:**

The learning objectives include:

To know the applications of Statistics, to learn and apply statistical techniques in the core course of their study. This course will give exposure to three applied fields of statistics viz. Time Series, Index Numbers, and Demographic methods. They will be having hands on practice of working on the data related to above mentioned fields.

#### **Course Outcomes:**

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

- The fundamental concepts of Index Numbers, Construction of price and quantity Index numbers. Construction of Wholesale and Consumer price Index and its significance.
- Time series data, components of time series data. Behavior and identification of the variation due to different components in the data.
- Different demographic methods. Measurement of mortality and fertility rates, reproduction and population growth measures.
- Construction and importance of Life Table.

## **B.Sc.-III Semester-V**

**DSES1-518**  
Time: 3 Hours

**Applied Statistics-I**

**Credits: 2**  
M.M.: 40+10\*  
\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

**Index Number:** Definition, problems involved in the construction of index numbers, calculation of index numbers-simple aggregate method, weighted aggregates method, simple average of price relatives, weighted average of price relatives, link relatives, chain indices, value index numbers, price and quantity index numbers.

### **UNIT-II**

Laspeyre's, Paasche's, Marshall-Edgeworth and Fisher's index numbers, time and factor reversal tests of index numbers, consumer price index number and its uses. Base shifting, splicing and deflating of index numbers.

### **UNIT-III**

**Time Series Analysis:** Definition, components of time series-trend, seasonal variations, cyclic variations, irregular component, illustrations, additive and multiplicative models, determination of trend: graphic method, semi-averages method, method of curve fitting by principle of least squares, moving average method. Analysis of seasonal fluctuations, construction of seasonal indices using method of simple averages, ratio to trend method and ratio to moving average method.

### **UNIT-IV**

**Demographic methods:** Sources of demographic data-census, register, adhoc survey, hospital records, measurement of mortality, crude death rate, specific death rate, standardized death rates, complete life tables and its main features, assumptions, descriptions and construction of life tables, uses of life tables, stationary and stable population, measurement of fertility-crude birth rate, general fertility rate, specific fertility rate, total fertility rate, measurement of population growth, gross reproduction rate, net reproduction rate.



### **Books recommended**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Applied General Statistics	Croxton F.E., Cowden D.J. & Kelin S.	Prentice Hall (1968)
2.	Demography	Cox P.R.	Cambridge Uni. Press (1976)
3.	Technical Demography	Ramakumar R.	New Age International (2018)
4.	Fundamentals of Applied Statistics	Gupta S.C. & Kapoor V.K.	Sultan Chand & Sons (2014)

## **B.Sc.-III Semester-V**

**DSES2-518**

**Bio-Statistics**

### **Course Objectives:**

The learning objectives include:

Biostatistics is one area of Applied Statistics that concerns itself with the application of statistical methods to medical, biological, epidemiological and health related problems.

### **Course Outcomes:**

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

- Designing and analysis of epidemiologic studies.
- Planning and design of clinical trials
- Using software to analyze the data of different study designs.
- Estimation of survival functions.

## **B.Sc.-III Semester-V**

**DSES2-518**

Time: 3 Hours

**Bio-Statistics**

**Credits: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT I**

Introduction to epidemiology, principles of epidemiologic investigation, Epidemiologic measures. Design and analysis of epidemiologic studies: types of studies, case-control studies, cohort studies, quantitative methods in screening.

### **UNIT II**

Introduction of clinical trials: Definition and type of trials, phases of clinical trials, designs of randomized controlled clinical trial (RCT), the need and ethics of clinical trials, overview of Phase I – IV trials, multicenter trials. Estimation and importance of sample size in research design.

### **UNIT III**

Planning Research and Data Generation: Research design, Primary and secondary data; Making survey-questionnaire, Data collection methods and arrangement; analysis of data using different study designs using statistical software like SPSS and R. National Sample survey, survey sampling and its methods.

### **UNIT IV**

**SURVIVAL ANALYSIS:** life table techniques, estimation of survival function – actuarial estimator, Kaplan – Meier estimator, total time on test, estimation under the assumption of IFR/DFR, tests of exponentiality against hazard function; Ageing classes( IFR,IFRA,NBU,NBUE) and their properties, Dual classes .

**Books recommended:**

1. Rothman ,K. J. and Greenland, S. (ed.) (1988):Modern Epidemiology, Lippincott-Raven.
2. Selvin, S. (1996): Statistical Analysis of Epidemiologic Data, Oxford University Press.
3. McNeil ,D. (1996): Epidemiological Research Methods. Wiley and Sons.
4. Jekel, J. F., Elmore, J. G. Katz ,D.L.: (1996). Epidemiology, Biostatistics and Preventive Medicine. WB Saunders Co.
5. Cox, and Oakes, D. (1984): Analysis of Survival Data, Chapman and Hall, New York.
6. Deshpande J. V. and Purohit S.G. (2015): Life time data / Statistical models and methods, 2<sup>nd</sup> Edition, word scientific
7. Gross A. J. and Clark, V.A. (1975): Survival Distribution: Reliability applications in the Biomedical Sciences, John Wiley and Sons.
8. Elandt – Johnson, R.E. Johnson N. L.: Survival Models and Data Analysis, John Wiley and Sons.
9. Miller, R. G. (1998): Survival Analysis, Wiley Interscience.
10. Kalbfleisch J. D. and Prentice R. (1980): The Statistical Analysis of failure Time data, John Wiley.

## **B.Sc.-III Semester-V**

**DSES3-519**

### **Numerical Methods and Fundamentals of Computers**

#### **Course Objectives:**

The learning objectives include:

To know about the concept of interpolation and extrapolation, methods of interpolation, Divided differences and their properties, Numerical integration, General quadrature formula for equidistant ordinates, Basics of Computer, Computer Arithmetic, Concepts of flow chart, algorithm and programming, Elementary idea of statistical software: SPSS.

#### **Course Outcomes:**

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

- Interpolation and extrapolation, methods of interpolation with equal and unequal intervals,
- General quadrature formula & Numerical integration
- Basic introduction of computers
- Binary operations and conversions and elementary idea of statistical software SPSS

## B.Sc.-III Semester-V

**DSES3-519 Numerical Methods and Fundamentals of Computers**

**Credits: 2**

Time: 3 Hours

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

**Numerical Methods:** Concept of interpolation and extrapolation, difference tables for operators, forward, backward and shift, and their relationship, methods of interpolation, Newton's formula for forward and backward interpolation with equal intervals, factorial notations, equidistant terms with one or more missing terms.

### **UNIT-II**

Divided differences and their properties, Newton formula for unequal intervals, Lagrange's method of interpolation, Numerical integration, General quadrature formula for equidistant ordinates, Trapezoidal rule, Simpson's  $1/3^{\text{rd}}$  and  $3/8^{\text{th}}$  formulae.

### **UNIT-III**

**Basics of Computer:** Introduction, origin, development, uses and limitation of computers. Types of computers, computer structure, input-unit, CPU, output unit, secondary storage, High Level and low level languages, compiler and interpreter.

**Computer Arithmetic:** Floating point representation of numbers, arithmetic operations with normalized floating point numbers. Number systems- Binary, decimal, octal and hexadecimal number systems and their conversions into each other. Binary arithmetic's, (Addition, subtraction, multiplication & division).

### **UNIT-IV**

**Flow charts and Algorithms:** Concepts of flow chart, algorithm and programming. Flow charts and algorithms for the following: Mean, median, mode, variance, covariance, coefficient of correlation and Straight line fitting. Trapezoidal rule, Simpson's  $1/3$  and  $3/8^{\text{th}}$  rules. Elementary idea of statistical software: SPSS

**Books recommended:**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Computer Fundamentals	Sinha P.K.	BPB Publication (2010)
2.	Introductory Methods of Numerical Analysis	Sastry S.S.	Prentice Hall (2012)
3.	Computer Based Numerical Algorithms	Krishnamurthy E.V. & Sen S.K.	Affiliated East West Press (2009)
4.	Computer Oriented Numerical Methods	Rajaraman V.	Prentice Hall (2019)

## **B.Sc.-III Semester-V**

**DSES4-519**

**Econometrics**

### **Course Objectives:**

The learning objectives include:

A broad knowledge of regression analysis relevant for analyzing 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 Outcomes:**

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

- The fundamental concepts of econometrics & Specification of the model.
- Extensions of two variable Linear Regression Model.
- Autocorrelation, Multicollinearity & Heteroscedasticity.
- Autoregressive and Lag models.



## B.Sc.-III Semester-V

**DSES4-519**

Time: 3 Hours

**Econometrics**

**Credits: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT I**

Econometrics – definition, scope, methodology and types. Simple Linear Regression Model, Estimation of model by method of ordinary least squares, Desirable Properties of an Estimator, Multiple Regression.

### **UNIT II**

Extensions of the two-variable linear regression model: Regression through the origin,  $r^2$  for regression-through-origin model, scaling and units of measurement, regression on standardized variable, functional forms of regression models.

### **UNIT III**

Tests and Remedial Measures for Heteroscedasticity, Autocorrelation and Multicollinearity, Specification Errors

### **UNIT IV**

Autoregressive and Distributed Lag Models – Estimation methods, Koyck and Almon's Approach to distributed- lag models. Qualitative (dummy) independent variables, dummy variables and interaction effects.

#### **Books recommended:**

1. Gujarati, D.N. and Sangeetha, S.(2007), Basic Econometrics (4th Edition) McGraw Hill ,New Delhi.
2. Johnson J.and Dinardo,J.(1994), Econometric Methods, McGraw Hall Book Co., London
3. Kmenta J. (1998), Elements of Econometrics, University of Michigan Press, New York
4. Koutsoyiannis, A. (2004), Theory of Econometrics, (2<sup>nd</sup> edition)Palgrave Macmillan Limited.
5. Maddala G.S. and Lahiri, K.(2009), Introduction to Econometrics (4<sup>th</sup> edition), John Wiley and Sons.

## **B.Sc.-III Semester-V**

**DSES-520**

**Practical-V**

### **Based on Applied Statistics-I**

#### **Course Objectives:**

The learning objectives include:

Applications of Statistics, to learn and apply statistical techniques in the core course of their study.

#### **Course Outcomes:**

On completion of this course students will be able to:

1. Construct price and quantity Index numbers, Wholesale and Consumer price Index
2. Find trend using different methods.
3. Obtain other components of time series.
4. Measure different mortality and fertility rates, reproduction rates, population growth measures and construction of Life Table.

**Or**

### **Based on Bio-Statistics**

#### **Course Objectives:**

The learning objectives include:

Application of statistical methods to medical, biological, epidemiological and health related problems.

#### **Course Outcomes:**

On completion of this course students will be able to:

1. Estimate the sample size in different research designs.
2. Prepare the survey questionnaire & analyze the data.
3. Prepare the reports of surveys.
4. Estimate survival functions.

And

**Based on Numerical Methods**

**Course Objectives:**

The learning objectives include:

To know about the concept of interpolation and extrapolation, methods of interpolation, Divided differences and their properties, Numerical integration,

**Course Outcomes:**

On completion of this course students will be able to:

1. Construct difference table and to find missing value.
2. Solve interpolation for equal intervals.
3. Solve interpolation for unequal intervals.
4. Solve Numerical integration

Or

**Based on Econometrics**

**Course Objectives:**

The learning objectives include:

A broad knowledge of regression analysis relevant for analyzing economic data, interpretation and critical evaluation of the outcomes of empirical analysis.

**Course Outcomes:**

On completion of this course students will be able to:

1. Solve, test and forecast problems based on General linear model.
2. Solve problems related to consequences of Multicollinearity, Autocorrelation, Heteroscedasticity.
3. Estimate General linear model under Autocorrelation, Heteroscedastic disturbance terms.
4. Solve problems related to General linear model under Autoregressive and Lag models.

**B.Sc.-III Semester-V**

**DSES-520**  
Time: 3 Hours

**Practical-V**

**Credit: 2**  
M.M.: 40+10\*  
\*Internal Assessment

**Note: Five questions will be set. The candidate will be required to attempt any three.**

**Based on Applied Statistics-I**

1. To calculate price and quantity index numbers using the formulae given by Laspyre, Paasche, Marshal- Edgeworth and Fisher.
2. To obtain cost of living index numbers for the given data using (i) Aggregate Expenditure Method. (ii) Family Budget Method
3. To test the given data using the formulae given by Laspyre, Paasche, Marshal-Edgeworth and Fisher, satisfy reversal tests.
4. To work out trends using curve fitting method for given data.
5. To work out trends using moving average method for given data.
6. To obtain seasonal variation indices using simple average method.
7. To obtain seasonal variation indices using ratio to moving average method.
8. To calculate the crude and standardized death rates of the population using Direct Method and Indirect Method regarding one of the population as standard population.
9. To calculate the following for the given data CDR, CBR, Sex/Age SDR, GFR, TFR, GRR, NRR.
10. . To complete the given incomplete life table by computing various elements of life table.

**Or**

**Based on Bio-Statistics**

1. Estimation of epidemiologic studies.
2. Estimation of sample size in different research designs.
3. Planning and design of randomized controlled clinical trial (RCT).
4. Preparation of survey-questionnaire, Data collection methods, statistical analysis and interpretation of collected data using statistical software.
5. Summary reports of different National surveys in India.
6. Estimation of life table and survival analysis.

**And**

### **Based on Numerical Methods**

1. To interpolate the required value for the given data using Newton's
  - (i) Forward interpolation formula for equal intervals
  - (ii) Backward interpolation formula for equal intervals.
2. To interpolate the required value for the given data of using
  - (i) Newton's divided difference formula
  - (ii) Lagrange's interpolation formula.
3. To evaluate the integral of the type  $\int_a^b f(x) dx$  using
  - (i) Trapezoidal rule, (ii) Simpson's one-third rule
  - (ii) Simpson's three- eight rule

**Or**

### **Based on Econometrics**

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 concerning specification errors
5. Problems related to consequences of
  - (i) Multicollinearity
  - (ii) Autocorrelation (AR(I))
  - (iii) Heteroscedasticity
6. Estimation of problems of General linear model under Heteroscedastic distance terms.
7. Problems on Autoregressive and Lag models.

## **B.Sc.-III Semester-VI**

**SECS1-601**

### **Statistical Data Analysis Using R**

#### **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 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.
- Flow controls ,Random number generation and sampling procedures, Multiple regression.
- Testing of hypothesis, p-value and confidence interval, Importing data, Code editing in R.

## **B.Sc.-III Semester-VI**

**SECS1-601**

Time: 3 Hours

**Statistical Data Analysis Using R**

**Credits: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one.

### **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.

**Books recommended:**

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.



## **B.Sc.-III Semester-VI**

**SECS2-601**

**Statistical Simulation**

### **Course Objectives:**

The learning objectives include:

Concept of simulation and simulation modeling, generation of Pseudo random number generators as well as from standard statistical distributions, Monte-Carlo simulation technique, application of simulation techniques.

### **Course Outcomes:**

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

- How simulation may be used to understand the behavior of real world systems by utilizing mathematical models with an emphasis on simulation.
- How to generate random numbers by the different methods.
- Various applications of simulation.
- Advantages and disadvantages of simulation, Scope of simulation technique.

## **B.Sc.-III Semester-VI**

**SECS1-601**

Time: 3 Hours

**Statistical Simulation**

**Credits: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one.

### **Unit I:**

Introduction: Need for simulation, general principles, simulation models, event type simulation.

### **Unit II:**

Random numbers generation: Pseudo random number generators; the inverse transform method, Discrete and Continuous distributions, Transformation of random variables.

### **Unit III:**

Applications of simulation: Monte Carlo simulation technique. Inventory problems, Queueing systems.

### **Unit IV:**

Advantages and disadvantages of simulation, simulation of languages, Scope of simulation technique.

### **Books recommended:**

1. Fishman, G.S. (1996). Monte Carlo - Concepts, Algorithms and Applications, Springer.
2. Taha, H. A. (2010). Operations Research. An Introduction, 9<sup>th</sup> Ed, Pearson.
3. Reitman, J. (1971). Computer simulation Applications, John Wiley & Sons.
4. Swarup, K. Gupta, P.K. and Mohan, M. (2014). Operations Research, 15<sup>th</sup> Ed, Sultan Chand & Sons.
5. Payer T.A. (1982). Introduction to simulation, McGraw Hill.
6. Voss, J. (2013). An introduction to statistical computing: A simulation-based approach, 1<sup>st</sup> Ed., Wiley series in computational statistics.

## **B.Sc.-III Semester-VI**

**DSES5-618**

**Applied Statistics-II**

### **Course Objectives:**

The learning objectives include:

To know about official statistical system in India and functions of different agencies, will help students to know the applications of Statistics and to learn and apply the learned techniques in the core course of their study, concept of Statistical Quality Control, its characteristics and applications, will also be having hands on practice of working on the data related to above mentioned fields.

### **Course Outcomes:**

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

- Present official statistical system in India, functions of C.S.O. and N.S.S.O
- Statistical Quality Control, Use of Statistical methods in industrial research and practice.
- Statistical process control tools- Control charts for variables and attributes.
- Acceptance Sampling Plan, important definitions related to it, single and double sampling plans

## B.Sc.-III Semester-VI

**DSES5-618**

Time: 3 Hours

**Applied Statistics-II**

**Credits: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

**Indian official statistics:** Introduction. Indian statistical system. Statistical offices at the centre. Statistical offices in the states. Population statistics. Agricultural statistics. Industrial statistics. Trade statistics. Price statistics. Statistics of labour and employment. Statistics of transport and communication. Financial and banking statistics.

### **UNIT-II**

**Statistical Quality Control:** Meaning and uses of SQC, causes of variations in quality, product and process control, control charts, 3- $\sigma$  control limits, control chart for variables-  $\bar{X}$  and R chart, criteria for detection of lack of control in  $\bar{X}$  & R Charts, Interpretation of  $\bar{X}$  & R charts.

### **UNIT-III**

Control chart for standard deviation ( $\sigma$  chart), control charts for attributes: 'p' chart and 'c' chart, natural tolerance and specification limits.

### **UNIT-IV**

**Acceptance sampling :** Problem of lot acceptance, stipulation of good and bad lots, producer's and consumers risks, single and double sampling plans, their OC functions, concepts of AQL, LTPD, AOQL, average amount of inspection and ASN function.

### **Books recommended**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Statistical Quality Control	Grant E.L.	McGraw Hill (2017)
2.	Statistical Methods in Quality Control	Cowden D.J.	Asia Pub. Society (1957)
3.	Fundamentals of Applied Statistics	Gupta S.C. & Kapoor V.K.	Sultan Chand & Sons (2018)
4.	Fundamentals of Statistics, Vol. II	Goon A.M., Gupta M.K. & Dasgupta B.	World Press Calcutta (2016)

## **B.Sc.-III Semester-VI**

**DSES6-618**

**Linear Models**

### **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 Outcomes:**

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

- Theory and estimation of Linear Models and Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Techniques for Analysis of Variance and Covariance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics, prediction from a fitted model, Residuals and Outliers, Lack of fit and pure error and remedies to deal with them.

## **B.Sc.-III Semester-VI**

**DSES6-618**

Time: 3 Hours

**Linear Models**

**Credits: 2**

M.M.:40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT I**

Linear Estimation: Gauss-Markov setup, normal equations and least squares estimators, variances and covariance of least squares estimators, estimations of error variance, properties of least squares estimators, 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.

**Books recommended:**

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.



## **B.Sc.-III Semester-VI**

**DSES7-619**

### **Operations Research**

#### **Course Objectives:**

The learning objectives include:

To explain the meaning of operations research, O.R models, its characteristics, formulation of L.P.P, solving them using Graphical procedure, simplex method, Big-M, Two-phase method, Duality in L.P.P, Transportation Problem, different methods to find initial feasible solutions and finding the optimum solution.

#### **Course Outcomes:**

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

- Fundamental concepts of Operational Research Techniques
- Linear Programming Problems and their formulations.
- Graphical procedure and simplex method, to solve for artificial variables using Big-M & Two-Phase methods, Duality & situations where duality is fruitful
- How to minimize cost for any balanced transportation problem using different methods.

## **B.Sc.-III Semester-VI**

**DSES7-619**

Time: 3 Hours

**Operations Research**

**Credits: 2**

M.M.: 40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

### **UNIT-I**

Objective of O.R., nature and definitions of O.R., Scope of O.R., Meaning and necessity of O.R. models, classification of O.R. models, Advantages & disadvantages of O.R. models. Steps in model formulation, principles of modeling. Characteristics of a good model, Allocation problems.

### **UNIT-II**

Linear programming problem (LPP): Definition, objective function, constraints, graphical solution of L.P.P., limitations of graphical method, Simplex method to solve L.P.P., concept of initial basic feasible solution, computation procedure for Simplex method.

### **UNIT-III**

Artificial variable techniques: Big-M method, Two-phase method. Duality in Linear Programming; Concept of duality, Fundamental properties of duality.

### **UNIT-IV**

Transportation Problem (T.P.): Formulation, Basic feasible solution. Different methods to find initial feasible solution: North-West corner rule, Row minima method, column minima method, Matrix minima method (Least cost entry method), Vogel's Approximation method (or Unit cost penalty method). UV-method (Modi's method) for finding the optimum solution of T.P.

### **Books recommended**

<b>S. No.</b>	<b>Title of Book</b>	<b>Name of author</b>	<b>Publisher &amp; Year</b>
1.	Linear Programming	Hadley G.	Narosa (2002)
2.	Operations Research: An Introduction	Taha H.A.	Macmillan Pub. Co. (2019)
3.	Operations Research	Goel B.S. & Mittal S.K.	Pragati Prakashan (2014)
4.	Operations Research	Sharma S.D.	KedarNath& Co. (2017)
5.	Operations Research	Sharma J.K.	Macmillan Pub. (2017)

**B.A/B.Sc.-III Semester-VI**

**(DSES8-619)**

**Actuarial Statistics**

**Course Objectives:**

The learning objectives include:

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

**Course Outcomes:**

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

- Probability models and loss distributions.
- Principles of compounds interest.
- Assurance and Annuity contracts.
- Computation of premiums and settlement of claims.

**B.A/B.Sc.-III Semester-VI**

**DSES8-619**

Time: 3 Hours

**Actuarial Statistics**

**Credits: 2**

M.M.:40+10\*

\*Internal Assessment

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising 5 to 8 short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one question from each unit and the compulsory one. The weightage of all the questions will be the same.

**Unit I**

Probability Models, Loss distributions: modelling of individual and aggregate losses, fitting distributions to claims data, Risk models: models for individual claims and their sums, Distribution of aggregate claims, Compound distributions and applications, Introduction to Utility theory and Expected Utility Criterion.

**Unit II**

Survival function, curate future lifetime, force of mortality, life tables with examples. Multiple life functions, joint life and last survivor status. Multiple decrement model.

Principles of compound interest : Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor.

**Unit III**

Assurance and annuity contracts: definitions of benefits and premiums, various types of assurances and annuities and their relationships, present value, formulae for mean and variance of various continuous (payable immediately on death) and discrete (payable at the end of year of death) payments.

**Unit IV**

Calculation of various payments from life tables: principle of equivalence, net premiums, prospective and retrospective provisions/reserves.

## References:

1. Boland, P. (2007). *Statistical and Probabilistic Methods in Actuarial Science*. Chapman and Hall/CRC.
2. Borowaik, D.S. and Shapiro, A. F. (2013). *Financial and Actuarial Statistics: An Introduction*. 2nd Edition. Marcel Dekker Inc., New York-Basel.
3. Bowers, N. L., Gerber H. U., Hickman, J. C., Jones, D. A. and Nesbitt, C. J. (1997). *Actuarial Mathematics*, 2nd Edition, Society of Actuaries, USA.
4. Deshmukh, S.R. (2005). *Actuarial Statistics: In Introduction Using R*. Narosa Publishing House, New Delhi.
5. Dickson, D.C.M.(2016). *Insurance Risk and Ruin*, Second Edition, Cambridge University Press.
6. Klugman, S. A., Panjer, H. H. and Willmot, G. E. (2013). *Loss Models: Further Topics*, 4<sup>th</sup>Edition. Wiley-Interscience.
7. Promislow, S. D. (2014). *Fundamentals of Actuarial Mathematics*. 3rd Edition. Wiley.

## **B.Sc.-III Semester-VI**

DSES-620

### **Practical-VI**

#### **Based on Applied Statistics-II**

##### **Course Objectives:**

The learning objectives include:

Concept of Statistical Quality Control, different tools of quality control, their construction and interpretation.

##### **Course Outcomes:**

On completion of this course students will be able to:

1. Control charts for variables;  $\bar{X}$  and R- chart with their interpretation
2. Control charts for variables;  $\bar{X}$  and  $\sigma$ - chart with their interpretation
3. Control charts for attributes, d, p and c-chart with their interpretation.
4. Acceptance Sampling Plan, single and double sampling plans

**Or**

#### **Based on Linear Models**

##### **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 Outcomes:**

On completion of this course students will be able to:

1. Solve for Distribution of Quadratic forms.
2. Solve Simple and Multiple linear regression models.
3. Perform Analysis of Variance and Covariance under fixed effects model.
4. Assessment of the quality of the fit using classical diagnostics, prediction from a fitted model, Residuals and Outliers

**And**

**Based on Operations Research**

**Course Objectives:**

The learning objectives include:

Formulation of L.P.P, solving them using Graphical procedure, simplex method, Big-M, Two-phase method, Duality in L.P.P, Transportation Problem

**Course Outcomes:**

On completion of this course students will be able to:

1. Formulate L.P.P and to solve them using graphical method.
2. Solve L. P.P using Simplex method.
3. Artificial variable techniques: Big-M method, Two-phase method.
4. To minimize cost for any balanced transportation problem using different methods.

**Or**

**Based on Actuarial Statistics**

**Course Objectives:**

The learning objectives include:

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

**Course Outcomes:**

On completion of this course students will be able to

1. Fit distributions to claim data, risk models for individual claims.
2. Compute risk for different utility functions.
3. Find mean and variance of various payments for assurance and annuity contracts.
4. Calculate various payments from Life tables using principle of equivalence.



**B.Sc.-III Semester-VI**

**DSES-620**  
Time: 3 Hours

**Practical-VI**

**Credit: 2**  
M.M.: 40+10\*  
\*Internal Assessment

**Note: Five questions will be set. The candidate will be required to attempt any three.**

**Based on Applied Statistics-II**

1. To construct  $\bar{X}$  and R- chart, and comment on the state of control of the process.
2. To construct p-chart and d-chart, and comment on the state of control of the process.
3. To obtain control limits for number of defects and comment on the state of control plotting the appropriate chart.
4. To obtain control limits for number of defects per unit and comment on the state of control plotting the appropriate chart.
5. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.
6. Calculation of process capability and comparison of 3-sigma control limits With specification limits

**Or**

**Based on Linear Model**

1. Estimation of X, when X is
  - (i) a full rank matrix.
  - (ii) not a full rank matrix.
2. Distribution of Quadratic forms.
3. Simple and Multiple Linear Regression.
4. Tests for Linear Hypothesis.
5. Bias in regression estimates.
6. Analysis of Covariance of a one way classified data.
7. Residual Analysis.

**And**

**Based on Operations Research**

1. Mathematical formulation of L.P.P and solving the problem using graphical Method, Simplex technique, Big M method and Two-Phase method involving artificial variables.
2. Identifying Special cases by Graphical and Simplex method and interpretation of
  - (i) Degenerate solution
  - (ii) Unbounded solution
  - (iii) Alternate solution
  - (iv) Infeasible solution
3. Allocation problem using Transportation model

**Or**

**Based on Actuarial Statistics**

1. Modelling of individual and aggregate losses.
2. Fitting distributions to claims data, Risk models for individual claims and their sums.
3. Finding distribution of aggregate claims, and applications of compound distributions
4. Risk computation for different utility functions.
5. Finding survival function, curate future lifetime, force of mortality and problems based on life tables.
6. Problems on joint life and last survivor status and multiple decrement model.
7. Finding mean and variance of various continuous and discrete payments for assurance and annuity contracts.
8. Calculation of various payments from life tables using principle of equivalence, net premiums, prospective and retrospective provisions/reserves.

**KURUKSHETRA UNIVERSITY, KURUKSHETRA**  
**(Established by the State Legislature Act XII of 1956)**  
**(‘A+’ Grade, NAAC Accredited)**



Scheme of Examination and Syllabus of  
M.Sc. Statistics CBCS w.e.f. session 2020-21 in Phased manner

**DEPARTMENT OF STATISTICS & OPERATIONAL RESEARCH**

CBCS CURRICULUM (2020-21)

Program Name: M.Sc. Statistics (CBCS)

# KURUKSHETRA UNIVERSITY, KURUKSHETRA

## Curriculum for M.Sc. Statistics (CBCS)

### Scheme of Examination

(With effect from the Academic Session 2020-2021 in phased manner)

The duration of the course leading to the degree of Master of Science (M.Sc.) Statistics shall be of two academic years, comprising of four semesters. The examinations of Semester –I and Semester- III are usually held in the month of December and those of Semester-II and Semester-IV in the month of May on the dates being notified by the controller of examinations.

There will be four theory papers and one practical paper in each semester. In addition, there will also be two Open Elective Papers, one each in Semester-II & III and will be opted by the students from the list of the Open Elective Papers of the other departments of faculty of Sciences.

Every student will be required to go for Training for at least two weeks in reputed Institute/Industry and after the completion of the training; the student will submit the Training Report. The evaluation of the Report will be done jointly by the Practical Examiners (External & Internal) in Semester -IV.

#### The details of the Scheme of Examination Semester-I

Paper No.	Nomenclature	Paper type	Credits	Contact hours per week	Internal marks***	External marks	Total marks	Duration of Exam (Hours)
ST-101	Measure and Probability Theory	Core	4	4	25	75	100	Three
ST-102	Statistical Methods and Distribution Theory	Core	4	4	25	75	100	Three
ST-103	Linear Algebra and Numerical Analysis	Core	4	4	25	75	100	Three
ST-104	Industrial Statistics	Core	4	4	25	75	100	Three
ST-105	Practical (Calculator and SPSS/R based)	Core	4	8	25	75	100	Four
			Total Credits-20		Total Marks -500			

**KURUKSHETRA UNIVERSITY, KURUKSHETRA**  
**Curriculum for M.Sc. Statistics (CBCS)**  
**Scheme of Examination**  
**(With effect from the Academic Session 2020-2021)**

**Semester – II**

Paper No.	Nomenclature	Paper type	Credits	Contact Hours per week	Internal marks***	External marks	Total marks	Duration of Exam (Hours)
ST-201	Applied Statistics	Core	4	4	25	75	100	Three
ST-202	Operations Research	Core	4	4	25	75	100	Three
ST-203	Inference-I	Core	4	4	25	75	100	Three
ST-204	Programming with C and R	Core	4	4	25	75	100	Three
ST-205	Practical (Computer based)	Core	4	8	25	75	100	Four
OE-	One open elective paper is to be opted by the students of Department out of the Open Elective papers offered by the departments of the Faculty of Sciences (other than the Department of Statistics & O.R)	Open Elective	2	2	15	35	50	Three
		Total Credits-22			Total Marks- 550			
OE-209	<b>Statistics -I</b> (This Open Elective paper will be offered by the Department of Statistics & O.R. to the students of other Departments of the Faculty of Sciences)		2	2	15	35	50	Three

**KURUKSHETRA UNIVERSITY, KURUKSHETRA**  
**Curriculum for M.Sc. Statistics (CBCS)**  
**Scheme of Examination**  
**(With effect from the Academic Session 2021-2022)**

**Semester –III**

Paper No.	Nomenclature		Paper type	Credits	Contact Hours per week	Internal marks***	External marks	Total marks	Duration of Exam. (Hours )
ST-301	Sampling Theory		Core	4	4	25	75	100	Three
ST-302	Inference-II		Core	4	4	25	75	100	Three
ST-303 & ST-304	Opt. (i) Optimization Techniques	Any Two	Elective **	4	4	25	75	100	Three
	Opt.(ii) Stochastic Processes Opt.(iii) Programming with Python Opt.(iv) Econometrics Opt. (v) Bio-Statistics Opt. (vi) Statistical Methods in Epidemiology Opt. (vii) Real and Complex Analysis		Elective **	4	4	25	75	100	Three
ST-305	Practical (Computer based)		Core	4	8	25	75	100	Four
OE-	One open elective paper is to be opted by the students of Department out of the Open Elective papers offered by the departments of the Faculty of Sciences (Other than the Department of Statistics & O.R)		Open Elective	2	2	15	35	50	Three
	Total Credits-22				Total Marks-550				
OE-309	<b>Statistics -II</b> (This Open Elective paper will be offered by the Department of Statistics & O.R. to the students of other Departments of the Faculty of Sciences)			2	2	15	35	50	Three

**KURUKSHETRA UNIVERSITY, KURUKSHETRA**  
**Curriculum for M.Sc. Statistics (CBCS)**  
**Scheme of Examination**  
**(With effect from the Academic Session 2021-2022)**  
**Semester –IV**

Paper No.	Nomenclature		Paper type	Credits	Contact Hours per week	Internal marks**	External marks	Total marks	Duration of Exam. (Hours )
ST-401	Multivariate Analysis		Core	4	4	25	75	100	Three
ST-402	Linear Estimation and Design of Experiments		Core	4	4	25	75	100	Three
ST-403 & ST-404	Opt. (i) Theory of Queues	Any Two	Elective **	4	4	25	75	100	Three
	Opt.(ii) Reliability and Renewal Theory		Elective **	4	4	25	75	100	Three
	Opt.(iii) Machine Learning								
	Opt. (iv) Information Theory								
	Opt.(v) Game Theory								
	Opt. (vi) Actuarial Statistics								
	Opt. (vii) Official Statistics								
ST-405	Practical (Calculator and SPSS/SYSTAT based)		Core	4	8	25	75	100	Four
Total Credits-20					Total Marks-500				

Note:

\*Total Credits for Two Academic Years: 84 (42+42).

\*\* The elective papers will be offered subject to availability of teaching faculty.

\*\*\* The marks of internal assessment/Internal marks will be based on the following criteria

**For Theory Papers:**

- (i) Class Test-I : 20 Marks  
Class Test-II  
(ii) Attendance : 5Marks

**For Practicals:**

- (i) Seminar/Viva-Voce/Test : 20 Marks  
for each practical paper  
(ii) Attendance : 5Marks

**For Open Elective theory papers**

- (i) Class Test-I : 10 Marks  
Class Test-II  
(ii) Attendance : 5 Marks

Marks for attendance will be given asunder:

- (1) 91% on wards: 5 Marks (2) 81%to90% : 4Marks  
(3) 75%to 80% : 3 Marks (4) 70%to 74% : 2 Marks#  
(5) 65%to 69% : 1 Mark#

# For students engaged in co-curricular activities of the Department /Institute only / authenticated medical grounds duly approved by the concerned Chairperson.

**Program Outcomes (PO) for Post Graduate Programmes (CBCS) in the Faculty of Sciences, Kurukshetra University, Kurukshetra**

<b>PO1</b>	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge gained during course of study
<b>PO2</b>	Research Aptitude	Capability to ask relevant/appropriate questions for identifying, formulating and analyzing the research problems and to draw conclusion from the analysis
<b>PO3</b>	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large
<b>PO4</b>	Problem Solving	Capability of applying knowledge to solve scientific and other problems
<b>PO5</b>	Individual and Team Work	Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.
<b>PO6</b>	Investigation of Problems	Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions
<b>PO7</b>	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices
<b>PO8</b>	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices
<b>PO9</b>	Life-Long Learning	Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout life
<b>PO10</b>	Ethics	Capability to identify and apply ethical issues related to one's work, avoid unethical behavior such as fabrication of data, committing plagiarism and unbiased truthful actions in all aspects of work
<b>PO11</b>	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects



**PSO for M.Sc. Statistics CBCS LOCF Programme**

**On successful completion of the programme a student will be able to**

1. Apply analytical and practical skills learned in the course work
2. Provide hands- on training of Statistical Softwares and computer skills to handle and analyze large database by making optimum usage of time and resources in industries.
3. Engage the students in life-long learning by pursuing higher education and participation in research and development activities to meet all challenges to transform them as responsible citizens of the nation.

## **M.Sc. Statistics Semester – I**

**(ST-101)**

### **Measure and Probability Theory**

#### **Course Objectives:**

The aim of the course is to pay a special attention to applications of Probability as a Measure. It provides the proper understanding of probability spaces for random variables, their sequences, various measures and measurable functions. The course will focus on the concept of law of large numbers and Central Limit Theorem.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Understand the concepts of random variables, different measures & their properties.
- Understand the concept of measurable functions and Integration of measurable functions.
- Apply the results based on various modes of convergence and their interrelationship.
- Describe the advanced techniques of Probability theory including Laws of large numbers and Central limit theorem.

## M.Sc. Statistics Semester – I

(ST-101)

### Measure and Probability Theory

(4Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all selecting one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit –I

Fields; sigma field, sigma-field generated by a class of subsets, Borel fields. Sequence of sets, limsup and liminf of sequence of sets, random variables, distribution function. Measure, probability measure, properties of a measure, Concept of outer measures, inner measures, Lebesgue measures and Lebesgue-Stieltjes measure.

#### Unit –II

Measurable functions: Sequence and algebra of measurable functions. convergence in measure. Integration of measurable function. Bounded convergence theorem, Fatou's Lemma, Monotone convergence theorem, General Lebesgue integral, Dominated convergence theorem.

#### Unit –III

Borel-Contelli Lemma, Borel 0-1 law, Kolmogorov's 0-1 law, Tchebycheff's and Kolmogorov's inequalities, various modes of convergence: in probability, almost sure, in distribution and in mean square and their interrelationship.

#### Unit –IV

Laws of large numbers for i.i.d. Sequences. Characteristic function its uniqueness, continuity and inversion formula. Applications of characteristic functions. Central limit theorems: De Moivre's-Laplace, Liapounov, Lindeberg-Levy and their applications

#### References:

1. Kingman, J. F. C. & Taylor S.J., (1966) : Introduction to Measure and Probability, Cambridge University Press.
2. Bhat, B.R.(2014) : Modern Probability Theory, Wiley Eastern Limited
3. Taylor, J. C.(1997) : An Introduction to Measure and Probability, Springer.
4. Royden, H.L .(2010) : Real Analysis, Pearson Prentice Hall.
5. Billingsley, P. (1986). : Probability and Measure, Wiley.
6. Halmos, P.R.(1974) : Measure Theory, Springer
7. Basu, A.K( 2017). : Measure Theory and Probability, PHI Learning (Pt.Lim.)

## **M.Sc. Statistics Semester – I**

### **(ST-102) Statistical Methods and Distribution Theory**

#### **Course Objectives:**

The course aims to shape the attitudes of learners regarding the field of statistics. This course will lay the foundation to probability theory and Statistical modeling of outcomes of real life random experiments through various Statistical distributions.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Explain the basic concepts of probability, marginal and conditional distributions.
- Understand the Mathematical Expectation, correlation and regression analysis.
- Understand the applications of discrete and continuous distributions.
- Understand the concepts and utility of sampling distributions.

## M.Sc. Statistics Semester – I

(ST-102)

### Statistical Methods and Distribution Theory

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit-I

Basic concepts of probability: Random variable, sample space, events, Definition of Probability : Classical, Relative Frequency and Axiomatic Approach, notations. Additive law of probability, theorem of total probability, theorem of compound probability and Baye's theorem. Random variables (discrete and continuous), Probability density function(pdf), Probability mass function(pmf), Distribution Function, Bivariate random variable, joint, marginal and conditional pmfs and pdfs.

#### Unit-II

Mathematical Expectation : Expectation and moments, expectation of sum of variates, expectation of product of independent variates, moment generating function. Tchebycheff's, Markov and Jensen inequalities, Relation between characteristic function and moments. Covariance, correlation coefficient , regression lines partial correlation coefficient, multiple correlation coefficient . Correlation ratio, rank correlation and intraclass correlation

#### Unit – III

Binomial, Poisson, Geometric, Negative binomial, Hypergeometric and Multinomial, Normal and log normal distributions.

#### Unit –IV

Uniform, Exponential, Laplace, Cauchy, Beta, Gamma distribution, Sampling distributions: Student – t distributions, F- distribution, Fisher's z – distribution and Chi-square distribution. Inter relations, asymptotic derivations. Simple tests based on t, F, chi square and normal variate z.

#### References:

1. Feller, W. (1968) : Introduction to probability and its applications, Vol.I, Wiley
2. Parzen, E. (1992) : Modern Probability Theory and its Applications, Wiley Interscience
3. Meyer, P.L. (1970) : Introductory Probability and Statistical Applications, Addison wesely.
4. Cramer, H.(2004) : Random variable and Probability Distribution, Cambridge University Press.
5. Kapur, J.N. (2010) : Mathematical Statistics & S.Chand & Co. & Sexena, H.C.

## **M.Sc. Statistics Semester – I**

### **(ST-103) Linear Algebra and Numerical Analysis**

#### **Course Objectives:**

To introduce the theory of Linear Algebra and Numerical Analysis in the scenario of statistics. The course will focus on Vector Spaces, Numerical Integration and Numerical solutions of ODEs.

#### **Course Outcomes:**

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

- Describe the fundamentals of linear algebra and Numerical Analysis.
- Understand the concepts of Vector Spaces and Linear transformations
- Apply the results based on real quadratic forms, its reduction and classification.
- Apply the results and formulas based on interpolation, divided differences and Numerical Integration.

## M.Sc. Statistics Semester – I

(ST-103)

### Linear Algebra and Numerical Analysis

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit – I

Vector Spaces: Linear dependence and independence , Basis and dimension of a vector space, examples of vector spaces .Linear transformations , Algebra of matrices , row and column spaces of a matrix , elementary matrices , determinant , rank and inverse of a matrix , null space and nullity ,Hermit canonical form. Solutions of matrix equations.

#### Unit – II

Orthogonal Transformations and Orthogonal matrix, Gram-Schmidt orthogonalisation process, characteristic roots and characteristic vectors, diagonalisation of a matrix, triangular form of a matrix .Real quadratic forms, reduction and classification of quadratic forms .

#### Unit – III

Difference and shift operators, identities involving separation of symbols and differences of zero, Newton's forward and backward interpolation formulae and estimation of the missing terms . Divided differences, Newton's and Lagrange's interpolation formulae for unequal intervals. Solution of systems of linear algebraic equations using Gauss elimination and Gauss-Seidal methods.

#### Unit – IV

Numerical Integration : Simpson's one-third and three eighth and Weddle's formulae, The Euler-Meclaurin's summation formula . Numerical solutions of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods.

#### References:

1. Hadley,G., (2002) : Linear Algebra
2. Datta,K.B.,(2016) : Matrix and Linear Algebra
3. Sushma, V : Linear Algebra(Macmillan)
4. Saxena.H.C : Calculus of Finite differences and numerical analysis.
5. Jain, M.K. (2019) : Numerical Methods for Scientific and Engineering
6. Guruswamy, B.(2009) : Computer Oriented Numerical Methods.

**M.Sc. Statistics Semester – II**  
**Industrial Statistics**

**(ST-104)**

**Course Objectives:**

The course aims to provide the theoretical knowledge about time series and S.Q.C.'s skills. It focuses on concepts and various techniques used in sampling and design in the context of quality control. It provides the knowledge to the students with the qualitative and analytical skills necessary to assist in planning, decision making and research within various industries. The course also aims to develop the skills of programming language R.

**Course Outcomes:**

On completion of this course students will be able to:

- Explain the concepts of Statistical Quality Control and Construct appropriate Quality Control Charts useful in monitoring a process.
- Apply various sampling inspection plans to real world problems for both theoretical and applied research and Assess the ability of a particular process to meet customer expectations.
- Understand to estimate Trend, Seasonal and Cyclic components of time series.
- Understand past and future behavior of phenomena under study and understand how a product quality can be improved and elimination of assignable causes of variations.



## M.Sc. Statistics Semester – I

(ST-104)

### Industrial Statistics

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit- I

Objectives of time series analysis, Components of time series, Measurement of secular trend: Method of mathematical curves (use of polynomial, logistic, Gompertz and lognormal functions), Method of moving averages Approximate formula( Spencer's 15-point and 21-point formulae); Method of variate- differencing and its use for estimation of variance of the random component. Measurement of seasonal fluctuations: Ratio-to moving average method, Ratio-to-trend method, Method of link relatives.

#### Unit- II

Measurement of cyclical fluctuations: Periodogram analysis. Different schemes which account for oscillations in a stationary time series, Concept of serial(auto) correlation and correlogram, Autoregressive series, Correlogram of (i) moving average,(ii) an autoregressive series and (iii) Harmonic series.

#### Unit- III

Introduction, Different types of quality measures, Rational sub-groups and technique of control charts, 3 sigma control limits and probability limits, control charts for variables (mean and range, mean and standard deviation), Control chart for number defective and fraction defective, Control charts for percent defective, Control chart for number of defects. Two types of control charts. Natural tolerance limits and specification limits; Modified control limits. Sampling inspection by attributes: single, double and multiple sampling plans.

#### Unit- IV

Sequential sampling inspection plans, comparison of three types of plans. Sampling inspection by variables: underlying principles, variables inspection with known and unknown standard deviation.

Cumulative sum control chart (Cusum chart): Advantage, Two-sided and one –sided decision procedure. The ARL curve: The ARL Curve for a Shewart chart and for a Cusum chart. Design of a Cusum chart and V-Mask.

#### References:

1. Kendall, M.G. (1989) : Time Series, Griffin London
2. Ekambaram, S.K.,(1963) : The Statistical Basis of Acceptance Sampling, Asia Publishing House.
3. Goon, A.M., Gupta, (2016) : Fundamentals of Statistics, Vol. II, ed. VI, Word Press M.K. & Dasgupta, B. Calcutta.
4. Montgomery, D.C.,(1996) : Introduction to Statistical Quality Control, J.Wiley.1985
5. Duncan, A.J. (1986) : Quality Control and Industrial Statistics, Richard O.Irwin, Homewood.IL

**M.Sc. Statistics Semester – I**  
**(ST-105) Practical (Calculator and SPSS/R based)**

**Course Objectives:**

The main objective of the course is to provide an understanding of basic statistical methods and ability to use through Softwares. During the course the students will train how to use SPSS and R for analysis. To acknowledge students the use of testing hypotheses for different parameter(s). It also provides practical knowledge about the concepts of Statistical Quality Control and Time Series.

**Course Outcomes:**

On completion of this course students will be able to:

- Obtain experience in using SPSS & R and Interpret the results of Statistical Analysis.
- Test the hypothesis using suitable statistical test(s).
- Understand to identify whether a process in statistical control or not.
- Understand to estimate Trend, Seasonal and Cyclic components of

## M.Sc. Statistics Semester – I

(ST-105)

**Practical (Calculator and SPSS/R based)**

(4Credits)

Max Marks 75+25\*\*\*

-Practical: 60

-Class Record: 05

-Viva-Vice: 10

\*\* \* Internal Assessment

Time: 4 hrs.

**Note: There will be 4 questions, the candidate will be required to attempt any 3 questions.**

### List of Practicals:

1. Testes of significance based on t-distribution.
  - (i) Testing the significance of the mean of a random sample from a normal population.
  - (ii) Testing the significance of difference between two sample means,
  - (iii) Testing the significance of an observed correlation coefficient.
  - (iv) Testing the significance of an observed partial correlation coefficient.
  - (v) Testing the significance of an observed regression coefficient.
2. Tests based on F-distribution.
  - (i) Testing the significance of the ratio of two independent population variances.
  - (ii) Testing the homogeneity of means (Analysis of variance).
3. Testing the significance of the difference between two independent correlation coefficients.
4. Testing the significance for
  - (i) A single proportion
  - (ii) Difference of proportions for large samples.
5. Testing the significance of the difference between means of two large samples.
6. Testing the significance of difference between standard deviations of two large samples.
7. Fitting of the
  - (i) Binomial distribution
  - (ii) Poisson
  - (iii) Normal distributionand their test of goodness of fit using  $\chi^2$  test.
8. Correlation and regression
  - (i) Pearson's coefficient of correlation
  - (ii) Spearman's rank correlation coefficient (with ties and without ties).
  - (iii) Fitting of the lines of regression.

9. Multiple and partial correlations

- (i) Multiple correlation coefficients
- (ii) Partial correlation coefficients
- (iii) Fitting of regression plane for three variates

10. Time series and SQC

- a. To obtain trends by using
  - (i) Method of Semi-Averages
  - (ii) Method of curve fitting
  - (iii) Method of moving average.
  - (iv) Spencer's 15 - point and 21 point -formulas.
  
- b. To obtain seasonal variation indices by using
  - (i) Ratio to trend method.
  - (ii) Ratio to moving average method.
  - (iii) Link relative method.
  
- c. To construct
  - (i)  $\bar{X}$  and R-chart
  - (ii) p-chart
  - (iii) c-chart and u-chartand comment on the State of Control of the process.

## **M.Sc. Statistics Semester - II**

**(ST-201)**

### **Applied Statistics**

#### **Course Objectives:**

The aim of this course is to provide adequate knowledge of Demography, Demand analysis and Index numbers. This course describes current population trends, in terms of fertility, mortality and population growth. It describes the structure and composition of populations and develop different measures used to keep track of the phenomena that affect populations.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Understand the basic concept of various measures of mortality and Life table.
- Describe the Abridged life tables and methods of population projection.
- Apply the results based on Demand Analysis
- Understand the concept of Index Numbers and Official Statistics.

**M.Sc. Statistics Semester - II**  
**Applied Statistics**

(ST-201)

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

Unit –I

Methods of obtaining demographic data, Rates and ratios, measurement of population at a given time , measurement of mortality : crude death rate , specific rates ,infant mortality rate , perinatal mortality rate , standard death rates . Graduation of mortality rates: Makehams and Gompertz graduation formula, Life table : Construction of a complete life table and its uses.

Unit –II

Abridged life tables: Kings method, Reed and Merrell's method, Greville's method, Keyfitz and Frauenhal's method and Chiang's method . Measurement of fertility: Crude birth rate , general fertility rate , age specific fertility rate , total fertility rate , gross reproduction rate and net reproduction rate . Stable and quasi-stable population, Methods of population projection, survival rates : UN model lifetable.

Unit –III

Demand Analysis– Laws of Demand and Supply, Price and Supply Elasticity of Demand. Partial and Cross Elasticity of Demand. Income Elasticity of Demand. Utility Function Methods of Determining Demand and Supply Curves from Family Budget and Time Series Data, Leontief's Method, Pigou's Method Engel Curve and its Different Forms,. Pareto's Law of Income Distribution. Curves of Concentration.

Unit –IV

Index Numbers and their Construction, Uses of Index Numbers. Price, Quantity and Value Relatives, Link and Chain Relatives, Laspeyer's, Paashce's, Marshall –Edge Worth and Fisher's Index Numbers, Chain Base Index Numbers, Tests for Index Numbers. Base Shifting, Splicing and Deflating of Index Numbers. Cost of Living Index Numbers. Official Statistics: National Sample Survey Office (NSSO) and Central Statistics Office (CSO) and their role in national development.

**References:**

1. Ramakumar, R. : Technical Demography, Wiley, Eastern Limited.
2. Gupta, S.C. & Kapoor, V.K. : Fundamental of applied Statistics, 1990. Sultan Chand and Sons,
3. Cox, P.R. (1970). : Demography, Cambridge University Press.
4. Keyfitz, N (1977). : Applied Mathematical Demography; Springer Verlag.
5. Spiegelman, M. (1969). : Introduction to Demographic Analysis; Harvard University
6. Goon, A.M., Gupta, M.K:(2016): Fundamental of Statistics Volume-II, & Dasgupta, B.
7. Guide to official Statistics (CSO) 1999.

## **M.Sc. Statistics Semester – II**

**(ST-202)**

### **Operations Research**

#### **Course Objectives:**

Operations Research aims to introduce students to use quantitative methods and techniques for effective decisions-making; model formulation and applications that are used in solving business decision problems.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Formulate Linear Programming problems and apply appropriate solving techniques to obtain optimum solution
- Build and solve Transportation Models and Assignment Models.
- Understand the concept of Game Theory, CPM and PERT.
- Solve the Inventory and Queueing models

**M.Sc. Statistics Semester – II**  
**Operations Research**

(ST-202)

(4 Credits)

Max Marks: 75+25\*\*\*

\*\* \*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

**Unit –I**

Convex sets, Linear Programming problems (LPP): Formulation, examples and forms, Hyperplane, Open and Closed half spaces. Feasible, basic feasible and optimal solutions. Solution of LPP by Graphical and Simplex method. Duality in linear programming.

**Unit –II**

Transportation Problems- Initial Basic Feasible Solution by North-West Corner Rule, Row minima method, Column minima method, Lowest Cost Entry Method, Vogel's Approximation Method, Optimum Solution of Transportation Problems. Assignment problem and its solution. Decision Theory : Algorithm for decision based problems, Types of decision making, Decision making under uncertainty : Criterion of optimism , Criterion of pessimism and Hurwicz criterion . Decision making under risks: EMV and EOL.

**Unit-III**

Game Theory : Terminology , two person zero sum game; game of pure strategy , reducing game by dominance, solution of game of mixed strategy without saddle point using linear programming method. Replacement models: replacement of items whose efficiency deteriorates with time and (i) The value of the money remains same during the period (ii) The value of the money also changes with time. Criterion of present value for comparing replacement alternatives. CPM (Critical path method) to solve the network problems and PERT.

**Unit – IV**

Inventory models: Deterministic inventory models ( D.I.M ) without shortages: EOQ model with constant rate of Demand, EOQ model with different rate of Demand, EOQ with finite rate of replenishment. D.I.M. with shortages : E O Q model with constant rate of Demand and scheduling time constant, E O Q model with constant rate of Demand and scheduling time variable. Simple Multi-item deterministic inventory model with constraint: model with limitation on space, model with limitation on investment. Queueing models : Introduction of queueing models, steady state solution of M/M/1 , M/M/1/N , M/M/C and M/M/C/N and their measures of effectiveness.

**References:**

1. Hadley, G.(1997): Linear Programming, Narosa Publications House.
2. Churchman, C.W.(1965) : Introduction to Operations Research John Wiley & Sons New York.
3. Goel, B.S. & Mittal, S.K.(2014): Operations Research, Pragater Prekshlen, John & Sons.
4. Gross, D. & Harris, C.M. (2008): Fundamentals of Queuing Theory
5. Sharma, S.D.(2012): Operation Research, KNRN



## M.Sc. Statistics Semester – II

(ST-203)

### Inference –I

#### Course Objectives:

The main objective of the course is to draw statistically valid conclusions about a population on the basis of a sample in a scientific manner. This course deals with fundamental concepts and techniques of statistical inference including point and interval estimation. Alternative philosophical approaches to inference such as likelihood methods, and fiducial methods will be described.

#### Course Outcomes:

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

- Apply various discrete and continuous probability distributions in modeling statistical processes. Familiar with the fundamental concepts of random variables as they apply to statistical inferences.
- Understand how sampling distributions are used in making statistical inferences and familiar with the fundamental concepts of statistical inference as they apply to problems found in other disciplines.
- Estimate unknown parameters of a given probability distribution using various estimation techniques.
- Understand (i) how probability is used to make statistical inferences, (ii) what inferential statistics are used for and (iii) know how to perform point and interval estimation.

## M.Sc. Statistics Semester – II

(ST-203)

### Inference–I

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit – I

Elements of Statistical Inference. Concept of likelihood function. Point estimation. Concept of consistency, unbiased estimators, correction for bias, minimum variance estimator, Cramer

– Rao inequality, Minimum Variance-Bound (M.V.B.) estimator, Bhattacharya Bounds, Uniqueness of minimum variance estimators, efficiency, Minimum mean- square estimation.

#### Unit – II

Sufficient statistic, Neymann factorization theorem sufficiency and minimum variance. Rao- Blackwell theorem. Lehman Scheffe's theorem. Distributions possessing sufficient statistics. Sufficiency when range depends on the parameter. The method of Least squares, The Least Squares estimator in the linear model, Optimum properties, Estimation of variance, the normality assumption.

#### Unit – III

Methods of estimation : Method of moments, Method of minimum chi-square and modified minimum chi-square , Method of maximum likelihood estimators and their properties, sufficiency, consistency of ML estimators. Hazurbazar's theorem, unique consistent ML estimators, efficiency and asymptotic normality of ML estimators.

#### Unit – IV

Interval estimation : Confidence intervals, confidence statements , central and non-central intervals , confidence intervals, Most selective intervals , Fiducial intervals : Fiducial inference in student's distribution , Problem of two means and its fiducial solution . Exact confidence intervals based on student's distribution, Approximate confidence- intervals solutions. Elementary Bayesian inference: Ideas of subjective probability, prior and posterior distribution, Bayesian intervals, Discussion of the methods of interval estimation.

#### References:

1. Kendall and Stuart (1979) : Advanced Theory of Statistics Vol.-II, Fourth edition Charles Griffin Co .Ltd London.
2. Rohtagi,V.K.. (2015) : Introduction to probability and Statistics (for & Saleh , A.K.Md. Ehsanes Numerical and Theoretical Applications), John Wiley and Sons.
3. Wald, A (2013) : Sequential Analysis, Dover publications, INC, New York.
4. Rao, C.R. (1970) : Advanced Statistical Methods in Biometric John Wiley&Sons, INC, NewYork.

## **M.Sc. Statistics Semester – II**

**(ST-204)**

### **Programming with C and R**

#### **Course Objectives:**

The objective of this course is to make the students familiar with the programming basics using C language. This course also focuses on the statistical programming using R programming language.

#### **Course Outcomes:**

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

- Understand the basics of C programming language such as data types, operators, control structures and functions.
- Understand and apply the concepts of pointers, arrays, structures and unions.
- Understand the basics of R programming language such as data types, operators, control structures and functions.
- Handle data manipulations and various statistical models.

## M.Sc. Statistics Semester – II Programming with C and R

(ST-204)

(4 Credits)

Max. Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** Total number of questions shall be nine. Question number one will be compulsory and will be consisting of short/objective type questions from complete syllabus. In addition to compulsory first question there shall be four units in the question paper each consisting of two questions. Student will attempt one question from each unit in addition to compulsory question. All questions will carry equal marks.

### Unit – I

Overview of C: History of C, Importance of C, Structure of a C Program. Elements of C: Character set, identifiers and keywords, Data types, Constants and Variables. Operators and their hierarchy & associativity. Input/output in C.

Control statements: Sequencing, Selection: if and switch statement; alternation, Repetition: for, while, and do-while loop; break, continue, go to statement. Functions: Definition, prototype, passing parameters, recursion.

### Unit – II

Storage classes in C: auto, extern, register and static storage class, their scope, storage and lifetime. Arrays: Definition, types, initialization, processing an array, passing arrays to functions. Pointers: Declaration, operations on pointers, use of pointers. String handling functions Structure & Union: Definition, processing, Structure and pointers, passing structures to functions. Data files: Opening and closing a file, I/O operations on files.

### Unit – III

Introduction to R: Overview of R programming, Evolution of R, Applications of R programming, Basic syntax; Basic Concepts of R: Reserved Words, Variables & Constants, Operators, Operator Precedence, Data Types, Input and Output; Data structures in R: Vectors, Matrix, List in R programming, Data Frame, Factor.

Control flow: If...else, If else() Function, For loop, While Loop, Break & next, Repeat Loop; Functions: R Functions, Function Return Value, Environment & Scope, R Recursive Function, R Infix Operator, R Switch function; Strings: String construction rules, String Manipulation functions

### Unit – IV

R packages: Study of different packages in R; R Data Reshaping: Joining Columns and Rows in a Data Frame, Merging Data Frames, Melting and Casting; Working with files: Read and writing into different types of files.

R object and Class Object and Class: R S3 Class, R S4 Class, R Reference Class, R Inheritance; Data visualization in R and Data Management: Bar Chart, Dot Plot, Scatter Plot (3D), Spinning Scatter Plots, Pie Chart, Histogram, Box plot, Plotting with Base and Lattice Graphics, Sorting Datasets, Merging Datasets; Statistical modelling and Databases in R: Mean, mode, median, Linear regression, Decision tree, K-means Clustering

### References

1. Gottfried, B. S. : Programming with C, Tata McGraw Hill
2. Balagurusamy, E. : Programming in ANSI C, McGraw-Hill
3. Yashwant, K : Let us C, BPB
4. Norman Matloff :The Art of R Programming-a tour of statistical software design by
5. Paul Teetor :R Cookbook Proven Recipes for Data Analysis, Statistics, and Graphics (O'Reilly Cookbooks)
6. Jeri R. H & Elliot P. K : Problem Solving and Program Design in C, Addison Wesley.
7. Kabacoff, Rob : R in Action Book
8. Zumel Nina, Mount John, Porzak Jim :Practical Data Science with R
9. Cotton Richard: Learning R : A Step-by-Step Function Guide to Data Analysis

## **M.Sc. Statistics Semester – II**

**(ST-205)**

### **Practical (Computer based)**

#### **Course Objectives:**

The objective of this course is to provide an understanding for the student on statistical concepts to include measurements of location, dispersion, probability distributions, regression, correlation analysis and testing the significance of small sample size with the help of C Programming. The main objective of the course is to provide an understanding of C programming for calculation of statistical data.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Calculate measures of location, dispersion, regression, correlation analysis and testing the significance of small sample with the help of C Programming.
- Compare different sets of data using C Programming.
- Able to fit probability distributions using C Programming.
- Understand data structures, use of pointers, memory allocation and data handling through files in 'C'.

(ST-205)

**M.Sc. Statistics Semester – II  
Practical (Computer based)**

(4 Credits)

Max Marks: 75+25\*\*\*

-Practical: 60

-Class Record: 05

-Viva-Vice: 10

-Time: 4 Hours

**Note: There will be 4 questions; the candidate will be required to attempt any 03 questions.**

**List of Practicals based on C**

1. Finding the mean and standard deviation for discrete and continuous data.
2. Computation of Moments, Skewness and Kurtosis of given data.
3. Computation of Karl Pearson's, Partial & Multiple correlation coefficient and Spearman's rank correlation coefficient.
4. Curve fitting, fitting of lines of regression.
5. Fitting of distribution: Binomial, Poisson and Normal.
6. Testing the significance of the mean of a random sample from a normal population.
7. Testing the significance of difference between two sample means,
8. Testing the significance of an observed correlation coefficient.
9. Testing the significance of an observed partial correlation coefficient.
10. Testing the significance of an observed multiple correlation coefficient.
11. Testing the significance of an observed regression coefficient.
12. Testing the significance of the ratio of two independent population variances.
13. To test the goodness of fit.
14. To test if the hypothetical value of the population variance is  $\sigma^2 = \sigma_0^2$  (say).

## Semester – II

Open Elective  
(OE-209)

### Statistics-I

#### Course Objectives

This course is designed to provide the fundamental concepts. This course is to provide an understanding for the student on statistical concepts to include measurements of location and dispersion, probability, probability distributions, regression, and correlation analysis. It provides knowledge about basic probability theory and its significance in the real world.

#### Course Outcomes:

On completion of this course students will be able to:

- Understand the importance and scope of Statistics.
- Calculate measures of location and dispersion with their applications.
- Understand the significance of statistics and probability in the real world
- Assess the nature of random variables and probability distributions.

## Semester – II

### Open Elective

(OE-209)

### Statistics-I

(2 Credits)

Max Marks: 35+15\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be ten questions in all i.e. five from each unit. The candidate will be required to attempt five questions selecting atleast two from each unit. The weightage of all the questions will be the same.

#### Unit -I

Meaning, importance and scope of statistics, Types of statistical data: primary and secondary data, qualitative and quantitative data, time series data, discrete and continuous data, ordinal, nominal, ratio and interval scales, Frequency distributions, cumulative frequency distributions, Diagrammatic representation of data: Bar diagrams, histogram, pie chart, measures of central tendency, Measures of dispersion, moments, skewness, kurtosis, Correlation coefficient , rank correlation, regression lines, partial correlation coefficient, multiple correlation coefficient.

#### Unit-II

Basic concepts of probability: Random experiment, sample space, events, different definitions of probability, Additive law of probability, conditional probability, Random variables: discrete and continuous random variables, Probability density function, distribution functions, mathematical expectation, moment generating function and characteristic function, Bivariate probability distributions: marginal and conditional distributions, Probability distributions: Binomial, Poisson, Normal, exponential, uniform, Central limit theorem.

#### References:

1. Gupta, S.C. & (2010): Fundamentals of Mathematical Statistics, Sultan Chand and Sons. Kapoor, V.K.
2. Gupta, S.C. & Kapoor, V.K. (2014): Fundamentals of Applied Statistics, Sultan Chand and Sons.
3. Goon, A.M., Gupta, M.K (2016) : Fundamentals of Statistics, Vol. II, ed. VI, Word Press & Dasgupta, B.



## M.Sc. Statistics Semester – III

(ST-301)

### Sampling Theory

**Course Objectives:** The main objectives of the sampling theory are to understand the advanced techniques of sample surveys and related issues which would be beneficial for the students to their further research. This course also focuses on how to obtain the best possible estimates of the population parameters.

**Course Outcomes:**

On completion of this course students will be able to:

- Understand the distinctive features of sampling schemes and its related estimation problems.
- Learn about the applications of sampling techniques: systematic, stratified and cluster sampling.
- Learn how to use the supplementary information for the purpose of estimation.
- Learn about probability proportionate to sampling (PPS) with replacement and without replacement methods and how to compare the results obtained under different sampling designs.

**M.Sc. Statistics Semester – III**  
**Sampling Theory**

(ST-301)

(4Credits)

**MaxMarks:75+25\*\*\***  
**\*\*\*Internal Assessment**  
**Time: 3 hrs.**

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

Unit -I

Basic finite population sampling techniques: Simple random sampling with replacement, Simple random sampling without replacement, stratified sampling and related results on estimation of population mean/total, Relative precision of Stratified and Simple random sampling techniques, Allocation problems in stratified sampling.

Unit –II

Use of supplementary information: Ratio estimation, bias and mean square error, estimation of variance, comparison with SRS, ratio estimator in stratified sampling, unbiased ratio-type estimators, regression and difference estimators, comparison of regression estimator with SRS and ratio estimator.

Unit –III

Systematic sampling (excluding circular systematic sampling) comparison with stratified and simple random sampling, double sampling for stratification and ratio estimate. Cluster sampling (equal clusters) and its efficiency relation between the variance of the mean of a single cluster and its size, Jesson's cost function and determination of optimum sampling unit. Sampling with unequal clusters, estimates of the means and their variances .

Unit –IV

Two stage sampling with equal first stage units, estimate of the population mean and its variance Repetitive surveys: Sampling over two occasions, probability proportionate to sampling (PPS) with replacement and without replacement methods [Cumulative total and Lahiri's method] and related estimators of a finite population mean [Horvitz Thompson and Desraj estimators for a general sample size and Murthy's estimator for a sample of size two].

**References:**

1. Chaudhuri A and Mukerjee R. (2017): Randomized Response, Theory and Techniques, New York: Marcel; Dekker Inc.
2. Cochran W.G. (2007) : Sampling Techniques (3rd Edition, Wiley.
3. Des Raj and Chandak (2013) : Sampling Theory, Narosa Publications House.
4. Murthy.M.N (1977) : Sampling Theory & Statistical Method Publishing Society, Calcutta.
5. Sukhatme et al (1984). : Sample Theory of Surveys with Applications. Iowa State University Press & IARS.

## M.Sc. Statistics Semester – III

(ST-302)

### Inference -II

**Course Objectives:** This course deals with concepts and techniques to arrive at decisions in certain situations where there is lack of certainty on the basis of a sample whose size is fixed or regarded as a random variable. Interpret statistical analysis and draw conclusions in context and in the presence of uncertainty. This course also focuses on Nonparametric tests deal with concepts of Empirical distribution function and order statistics.

**Course Outcomes:**

On completion of this course students will be able to:

- Understand the elements of Statistical decision theory.
- Know the concepts of Likelihood ratio test and its applications.
- Identify multiple applications where nonparametric approaches are appropriate.
- Perform and interpret various nonparametric tests.

## M.Sc. Statistics Semester – III

### Inference -II

(ST-302)

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit – I

Elements of Statistical decision theory. Neyman - Pearson lemma (with emphasis on the motivation of theory of testing of hypothesis) BCR and sufficient statistics. Testing a simple hypothesis against a class of alternatives. Most powerful test, Uniformly most powerful test and sufficient statistics, power function. One and two sided tests.

#### Unit –II

Composite hypotheses, An optimum property of sufficient statistics. Similar regions, Elementary ideas of complete statistics, Completeness of sufficient statistics. Likelihood ratio test and its applications, asymptotic distribution of LR statistic and asymptotic power of LR tests. Sequential Analysis. Concept of ASN and OC functions. Wald's sequential probability ratio test and its OC and ASN functions. Distribution of order statistics and range.

#### Unit –III

Non - parametric tests and their applications: Empirical distribution function and its properties (without Proof), Test of randomness (Test based on the total number of runs). One-sample and paired-sample techniques: The Ordinary Sign test and Wilcoxon Signed-rank test. Tests of Goodness of Fit: Chi-square Goodness of Fit, The Empirical distribution function, Kolmogorov- Smirnov tests, Independence in Bivariate sample: Kendall's Tau coefficient and Spearman's rank correlation.

#### Unit –IV

Generalized two-sample problem: The Wald-Wolfowitz Runs test, Kolmogorov-Smirnov two sample Test, Median Test, Mann-Whitney U Test, Linear Ranked tests for the Location and Scale problem: Wilcoxon Test, Mood Test, Siegel-Tukey Test, Klotz Normal-scores Test, Sukhatme Test. Kruskalwallis ANOVA test, Concept of Jackknife, Bootstrap methods.

#### References:

1. Kendall and Stuart (1967) : Advanced Theory of Statistics Vol.-II, Charles Griffin & Co. Ltd, London
2. Rohtagi, V.K. (2015) : Introduction to probability and Statistics (for Numerical and Theoretical Applications).  
Saleh Md. Ehsanes, A.K.
3. Wald, A (2013) : Sequential Analysis Dover Publications, INC. New York.
4. Gibbons, Jean Dickinson (2010) : Nonparametric Statistical Inference (For Unit –III & IV only). McGraw – Hill Book Co. New York.  
Subhabrata Chakraborti
5. Rao, C.R. (1970) : Advanced Statistical Methods in Biometric Research, John Wiley & Sons, INC, New York.

## M.Sc. Statistics Semester – III

(ST-303 & ST-304)Opt.(i)

### Optimization Techniques

(4 Credits)

#### Course Objectives:

The course aims to introduce and understand the concept of non linear optimization problems. It focuses on the concept of integer programming and some other advanced optimization techniques which are necessary to assist in planning, decision making and research within various institutions.

#### Course Outcomes:

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

- Deal with complex nature of non linear programming.
- Formulate real life problems with integer programming problem and apply appropriate solving techniques to obtain optimum solution.
- Solve the Quadratic Programming.
- Explain the concept of Dynamic Programming, Comparison of Linear & Dynamic Programming.

## M.Sc. Statistics Semester – III

(ST-303 & ST-304)Opt.(i)

### Optimization Techniques

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit-I

Artificial and unrestricted Variables, Two phase method, Big M-method, degeneracy and breaking the ties, Charne's perturbation method, revised Simplex method, Duality theory : Formulation and solution of dual problems, dual simplex algorithm and primal dual algorithm.

#### Unit-II

Non-Linear Programming Problems (NLPP): formulation of NLPP. Kuhn-Tucker Necessary and Sufficient Conditions of Optimality and Saddle Points. Integer Programming Problems(IPP), formulation of IPP, Solution of IPP: Gomory's algorithm for all integer programming problems, Branch and Bound Algorithm.

#### Unit-III

Quadratic Programming : Wolfe's and Beale's Method of Solutions. Separable Programming and its Reduction to LPP. Separable Programming Algorithm. Geometric Programming: Constrained and Unconstrained. Complementary Geometric Programming Problems. Fractional programming Algorithm and its computational procedure.

#### Unit – IV

Dynamic Programming: Principle of optimality , Cargo Loading problem, Inventory Problem, Computational Technique , Dimensionality Problem , Approximation by piecewise linear functions, Optimal path Problem, Sequencing Problem, Control Problem, Optimal page allocation Problem , Serial Multi Stage system , Comparison of Linear & Dynamic Programming.

#### References:

1. Hadley, G.(1997) :Linear programming, Narosa PublicationsHouse.
2. Vejda, S.(2009) :Mathematical Programming, DoverPublications.
3. Saul E.Gauss. :Linear programming Methods and Applications, DoverPublications.
4. Kambo, N. S. (2008) : Mathematical Programming Techniques, East –WestPressPvt. Ltd.
5. Mittal, K.V.(2016) :Optimization Methods, New Age International (P)Ltd.
6. Hadley, G.(1970): Non linear and Dynamic programming.

## **M.Sc. Statistics Semester – III**

### **Stochastic Processes**

**(ST-303 & ST-304) Opt. (ii)**

#### **Course Objectives:**

The course aims at:

Developing an awareness of the use of stochastic processes to build adequate mathematical models for random phenomena evolving in time. Acquainting students with notions of long-time behavior including transience, recurrence, and equilibrium to answer basic questions in several applied situations including branching processes and random walk models.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Understand the concept of stochastic processes and its classifications.
- Deal with Random walk models.
- Classify states and Markov chains according to their long term behavior.
- Derive the probabilities for the birth death process and Polya processes

## M.Sc. Statistics Semester – III

### Stochastic Processes

(4 Credits)

(ST-303 & ST-304) Opt. (ii)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit-I

Introduction to Stochastic processes, Classification of Stochastic processes according to state, space and time domain. Generating function, Convolutions, Compound distribution, Partial fraction expansion of generating functions.

#### Unit-II

Recurrent events, recurrence time distribution: necessary and sufficient condition for persistent and transient recurrent events & its illustrations and Notion of delayed recurrent event. Random walk models : absorbing, reflecting and elastic barriers, Gambler's ruin problem, probability distribution of ruin at  $n^{\text{th}}$  trial.

#### Unit-III

Markov chains: transition probabilities, classification of states and chains, evaluation of the  $n^{\text{th}}$  power of its transition probability matrix. Discrete branching processes, chance of extinction, means and variance of the  $n^{\text{th}}$  generation.

#### Unit-IV

Notions of Markov processes in continuous time and Chapman-Kolmogorov equations. The Poisson process: The simple birth process, the simple death processes. The simple birth and death process: The effect of immigration on birth and death process. The Polya Processes: Simple non-homogeneous birth and death processes.

#### References:

1. Bailey, N.T (1966) : The Elements of Stochastic Processes.
2. Medhi , J (2010). : Stochastic Processes, New Age International (P)Limited
3. Karlin , S.(1997) : Introduction to Stochastic Processing,  
Vol. I, Academic Press.
4. Basu, A.K.(2017) : Introduction to Stochastic Process, Narosa Publishing Hous



(ST-303 & ST-304) Opt. (iii)

## **M.Sc. Statistics Semester- III Programming with Python**

### **Course Objectives:**

The objective of this course is to provide basic knowledge of python with special emphasis on data science and machine learning packages.

### **Course Outcomes**

On completion of this course students will be able to:

- Solve simple to advanced problems using Python language.
- Implement different data structures using Python.
- Implement Object-oriented approach and numerical computations using Python and NumPy.
- Use python for data science and machine learning.

**M.Sc. Statistics Semester- III**  
**Programming with Python**

(4 Credits)

**Max. Marks: 75+25\*\*\***

**\*\*\*Internal Assessment**

**Time: 3 hrs.**

**(ST-303 &ST-304) Opt. (iii)**

**Note:** Total number of questions shall be nine. Question number one will be compulsory and will be consisting of short/objective type questions from complete syllabus. In addition to compulsory first question there shall be four units in the question paper each consisting of two questions. Student will attempt one question from each unit in addition to compulsory question. All questions will carry equal marks.

**Unit – I**

Introduction to Python Programming: Using Python, Input, Processing, and Output, Displaying Output with the Print Function, Comments, Variables, Reading Input from the Keyboard, Performing Calculations (Operators. Type conversions, Expressions), More about Data Output. Decision Structures and Boolean Logic: if, if-else, if-elif-else Statements, Nested Decision Structures, Logical Operators, Boolean Variables. Repetition Structures: Introduction, while loop, for loop, Calculating a Running Total, Input Validation Loops, Nested Loops.

Functions: Introduction, Defining and Calling a Void Function, Designing a Program to Use Functions, Local Variables, Passing Arguments to Functions, Global Variables and Global Constants, Value-Returning Functions Generating Random Numbers, Writing Our Own Value-Returning Functions, The math Module, Storing Functions in Modules.

**Unit – II**

File and Exceptions: Introduction to File Input and Output, Using Loops to Process Files, Processing Records, Exceptions.

Lists and Tuples: Sequences, Introduction to Lists, List slicing, Finding Items in Lists with the in Operator, List Methods and Useful Built-in Functions, Copying Lists, Processing Lists, Two-Dimensional Lists, Tuples. Strings: Basic String Operations, String Slicing, Testing, Searching, and Manipulating Strings. Dictionaries and Sets: Dictionaries, Sets, Serializing Objects. Recursion: Introduction, Problem Solving with Recursion, Examples of Recursive Algorithms.

**Unit – III**

Object-Oriented Programming: Procedural and Object-Oriented Programming, Classes, Working with Instances, Techniques for Designing Classes, Inheritance, Polymorphism.

NumPy - Introduction, Narray Object ,Data types, Array Attributes, Array Creation Routines, Indexing & Slicing, Advanced Indexing, Broadcasting, Iterating Over Array, Array Manipulation, Binary Operators, String Functions, Mathematical Functions, Mathematical Functions, Arithmetic Operations, Statistical Functions, Linear Algebra.

**Unit – IV**

Basic functions of matplotlib: Simple Line Plot, Scatter Plot, Density and Contour Plots, Histograms, Customizing Plot Legends, Colour Bars-Three-Dimensional Plotting in Matplotlib.

Introduction to Pandas Objects: Data indexing and Selection, Operating on Data in Pandas, Handling Missing Data, Hierarchical Indexing, Combining Data Sets.

Using Scikit-Learn for Linear Regression, Logistic Regression, Decision Tree, Naive Bayes, KNN, SVN, k Mean Clustering, Random Forest.

## References:

1. Zhang.Y., (2016): An Introduction to Python and Computer Programming, Springer Publications,
2. Gaddis Tony, Starting Out With Python
3. Vander Plas Jake (2016): ,Python Data Science Handbook - Essential Tools for Working with Data,  
O'Reily Media,Inc,
4. Guttag John V, (2013): Introduction to Computation and Programming Using Python, Revised and  
expanded Edition, MIT Press ,
5. Sedgewick Robert, Wayne Kevin, (2016): Introduction to Programming in Python:  
Dondero Robert, An Inter-disciplinary Approach, Pearson India Education  
Services Pvt. Ltd.,
6. Kenneth A. Lambert, Fundamentals of Python.
7. Joel Grus , (2016): Data Science from Scratch First Principles with Python, O'Reilly Media,
8. Padmanabhan T. R., (2016): Programming with Python, Springer Publications,
9. Halterman Richard L. : Fundamentals of Python Programming,
10. Thareja Reema : Python Programming – Using Problem Solving Approach,

## **M.Sc. Statistics Semester- III**

### **Econometrics**

**(ST-303 & ST-304) Opt. (iv)**

#### **Course Objectives:**

The objective of this course is to study more advanced topics in econometrics. Students are expected to have knowledge in statistics and multiple regression models. This course also focuses on theories developed to real-world data and interprets the estimation results in many different respects.

#### **Course Outcomes:**

On successful completion of this course students will be able to:

- Acquire knowledge of Two Variable Linear Regression Models.
- Learn how to apply the Tests based on Linear Restrictions on Regression Coefficients.
- Understand the concept of Heteroscedasticity and Tests for Heteroscedasticity.
- Deal with Simultaneous Equations Models

## **M.Sc. Statistics Semester- III** **Econometrics**

(ST-303 & ST-304) Opt.(iv)

**(4 Credits)**

**Max Marks: 75+25\*\*\***

**\*\*\*Internal Assessment**

**Time: 3 hrs.**

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

### Unit-I

Two Variable Linear Regression Model- Least Squares Estimators of Coefficients and Their Properties, Inference in Least Squares Model, The General Linear Regression Model, Ordinary Least Squares Estimator and its Properties, Inference in General Linear Regression Model. Maximum likelihood Estimates.

### Unit-II

Tests of Linear Restrictions on Regression Coefficients, Use of Extraneous Information on Regression Coefficients – Restricted Regression, Restricted Least Squares and its Properties, Mixed Regression and Properties of Mixed Regression Estimator, Specification Errors Analysis- Inclusion and Deletion of Explanatory Variables, Effect on Estimation of Parameters and Disturbance Variance.

### Unit-III

Heteroscedasticity, Tests for Heteroscedasticity –Bartlett's, Breusch-Pagan and Goldfeld-Quandt Tests Multicollinearity - Exact and Near Multicollinearity, Consequences and Detection of Multicollinearity, Farrar Glauber Test, Remedies for Multicollinearity, Ridge Regression Autocorrelation, Tests for Autocorrelation, Durbin Watson Test, Generalized Least Squares Estimation

### Unit-IV

Simultaneous Equations Models: Structural and Reduced forms, Identification Problem. Rank and Order Conditions of Identification, Estimation in Simultaneous Equations Models: Indirect Least Squares 2SLS Estimators, Instrumental Variable Method of Estimation. Limited Information maximum likelihood (LIML). Dummy Variable Technique for Testing Structural Stability of Regression Models and Comparing two regressions

### Reading List

1. Johnston, J. (1996): Econometric Models, McGrawHills
2. Jan Kmenta(1986): Elements of Econometrics, University of Michigan Press
3. Intriligator, M.D. : Economic models -techniques and applications, Prentice Hall
4. Maddala, G.S.(2009) : Econometrics, North Holland
5. Klein, L.R. : Applied Economics, Taylor and Francis
6. Koutsoyiannis, A.(2001): Theory of Econometrics, Palgrave.

## **M.Sc. Statistics Semester- III** **Bio-Statistics**

**(ST-303 & ST-304) Opt. (v)**

### **Course Objectives:**

The course aims at developing an awareness of the use of Biostatistics that is one of the areas of Applied Statistics.

This course is designed to teach the students about the basic principles of biostatistics.

### **Course Outcomes:**

On completion of this course students will be able to:

- Explain biostatistics and its uses in the field of public health.
- Understand the different types of mating.
- Apply the results based on genetic correlation and repeatability methods of estimation.
- Apply descriptive techniques commonly used to summarize public health data.

## M.Sc. Statistics Semester- III Bio-Statistics

(4 Credits)  
Max Marks: 75+25\*\*\*  
\*\*\*Internal Assessment  
Time: 3 hrs.

(ST-303 & ST-304) Opt. (v)

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

### Unit-I

Bioassays : Quantitative and quantal response, dose response relation. estimation of median effective dose, estimation of unknown concentration or potency, probit and logit transformations, Parallel line and slope ratio assays , potency, ratio, Feller's theorem. Tests for non-validity, symmetric and asymmetric : assays, Toxic action of mixtures.

### Unit-II

Types of mating: Random mating, Hardy-Weinberg equilibrium, Random mating in finite population. Inbreeding (Generation Matrix Approach) Segregation and linkage. Estimation of segregation and linkage parameters.

### Unit-III

Concept of gen frequencies. Estimation of gene frequencies Quantitative inheritance, Genetic parameters heritability, genetic correlation and repeatability methods of estimation. Selection and its effect, Selection Index, dialled and partially dialled Crosses.

### Unit-IV

Genotype environment interactions. Components of variance and Genotypic variance, Components of Covariance, Correlations between relatives, Genetic parameters; Heritability, Repeatability

### References:

1. Kempthorne, O : An Introduction to Genetical Statistics, Wiley Eastern
2. Jain, I.R. (2017) : Statistical techniques in quantitative genetics. Tata-McGraw Hill
3. Poti, S.J. (1984) : Quantitative study in life sciences, Vikas Publishing Ltd.
4. PremNarain. (1990): Bhatia : Handbook of Statistical Genetics, V.K. and Malhotra, I.A.S.R.I.P.K.
5. Daniell, W.W., Chad L. Cross(2014) : Bio Statistics – A foundation for analysis In health sciences , 3<sup>rd</sup> ed. Johnwiley
6. Falconer, D.S.(2009) : Introduction to quantitative Genetics (Longman Group Ltd.

## **M.Sc. Statistics Semester- III**

### **Statistical Methods in Epidemiology**

**(ST-303 & ST-304) Opt. (vi)**

#### **Course Objectives:**

This course aims at bio statistical methods and analysis of epidemiological studies. Course focuses on determinants of human disease and health outcomes with the application of methods to improve human health. The course develops basic statistical inference for risk measures according to the nature of the outcome variables (binary and ordinal, continuous, rate, time-to-event).

#### **Course Outcomes:**

On completion of this course students will be able to:

- Understand concepts of epidemiologic hypotheses and measures mortality/Morbidity
- Describe epidemiologic concepts of diseases and models of transmission of infection.
- Understand the strengths and limitations of various epidemiologic study designs.
- Identify sources of bias, confounding and effect modification in epidemiological studies.



## M.Sc. Statistics Semester- III

### Statistical Methods in Epidemiology

(4 Credits)

(ST-303& ST-304) Opt. (vi)

Max Marks:75+25\*\*\*

\*\* \*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit-I

Measures of disease frequency: Mortality/Morbidity rates, incidence, rates, prevalence rates. Sources of mortality/Morbidity statistics-hospital records, vital statistics records. Measures of accuracy or validity, sensitivity index, specificity index.

#### Unit-II

Epidemiologic concepts of diseases, Factors which determine the occurrence of diseases, models of transmission of infection, incubation period, disease spectrum and herd immunity. Observational studies in Epidemiology: Retrospective and prospective studies. Measures of association :Relative risk, odds ratio, attributable risk.

#### Unit-III

Statistic techniques used in analysis: Cornfield and Garts' method, Mantel-Haenszel method. Analysis of data from matched samples, logistic regression approach. Experimental Epidemiology: clinical and community trials. Statistical Techniques: Methods for comparison of the two treatments. Crossover design with Garts and McNamara test. Randomization in a clinical trial, sequential methods in clinical trials. Clinical lifetables.

#### Unit-IV

Assessment of survivability in clinical trials. Mathematical Modelling in Epidemiology: simple epidemic model, Generalized epidemic models, Reed First and Green wood models, models for carrier borne and host vector diseases.

#### References:

1. Lilienfeld and LiJenfeld (2015) : Foundations of Epidemiology, Oxford University Press.
2. Lanchaster, H.O.(1974) : An Introduction to Medical Statistics, John Wiley & Sons Inc.
3. Fleiss, J.L.(2003) : Statistical Methods for Rates and Proportions, Wiley InterScience.
4. Armitage(1975): Sequential Medical Trials, Second Edition, Wiley Blackwell.
5. Bailey, N.T.J. (1975): The mathematical theory of infectious disease and Applications, Griffin.

**M.Sc. Statistics Semester- III**  
**Real and Complex Analysis**

**(ST-303&ST-304) Opt. (vii)**

**Course Objectives:**

To explain the basic and advanced elements of real and complex analysis. The course will focus on Topology of Real Numbers and Functions of a Complex Variable and Their Analytic Properties. The course also focuses on Singularities, their Classification and Application of Cauchy's Residue Theorem.

**Course Outcomes:**

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

- Demonstrate an understanding of the concepts of real and complex number systems.
- Explain the concepts of Topology of Real Numbers
- Apply the results based on Functions of a Complex
  - (i) Variable and Their Analytic Properties
  - (ii) Singularities and Their Classification
- Apply the techniques of real and complex analysis in statistical applications.

## M.Sc. Statistics Semester- III

### Real and Complex Analysis

(ST-303&ST-304) Opt. (vii)

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit-I

Topology of Real Numbers: Open Set, Closed Set, Limit Point of a Set, Bounds of a Set. Convergence and Divergence of Sequences. Cauchy's Theorem on Limits, Sequence and Series of Functions and Their Convergence Properties.

#### Unit-II

Functions of a Complex Variable and Their Analytic Properties. Cauchy's Riemann equations. Power Series and its Radius of Convergence. Elementary idea of Mobius Transformation, Cross Ratio, Invariant Point and Critical point.

#### Unit-III

Regular and Rectifiable Arcs. Contour. Domains: Connected, Simply Connected and Multiply Connected. Complex Line integrals. Cauchy's Theorem, Cauchy's Integral Formulae and Inequality. Morera's Theorem. Liouville's Theorem. Taylor and Laurent Series

#### Unit-IV

Singularities and Their Classification. Poles and Zeros of a Meromorphic Function, Argument Principle. Rouché's Theorem. Fundamental Theorem of Algebra. Residues. Cauchy's Residue Theorem. Application of Cauchy's Residue Theorem for Evaluation of Integrals of Real Valued Functions.

#### References:

- 1 Narayan, Shanti, Mittal P.K. (2005) : A Course of Mathematical Analysis ,S.Chand.
2. Malik,S.C. &Arora,Savita(2017): Mathematical Analysis, New Age International.
3. Copson, E.T. (1970): Introduction to the Theory of Functions of a  
Complex Variable, Clarendon Press Oxford.
4. Convey, John B. (1996): Functions of one Complex Variable, Springer.
5. Sharma, J.N. (2014): Function of a Complex Variable, Krishna Parkashan, Media Ltd., Meerut.
6. Goyal and Gupta.(2016): Function of a complex Variable,,Pargati Parkashan Meerut.
7. Malik, S.C. (2016): Real and Complex Analysis, Jeevan Sons Publication, New Delhi.

## **M.Sc. Statistics Semester- III**

### **Practical (Computer based)**

**(ST-305)**

**Course Objectives:** The objective of this course is to provide Knowledge to student about sampling theory with the help of C++ Programming. The main objective of the course is to provide an understanding of C++ programming for calculation and comparison of statistical data.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Understand different methods of sample selection and analyzing data using C++.
- Estimate the population total, population mean and variance of estimator for different sampling designs with the help of C++ Programming
- Compare the ratio estimator with mean per unit estimator under simple randomsampling using C++.
- Compare the regression, ratio and mean per unit estimates from a simple randomsample using C++.

## M.Sc. Statistics Semester- III

(ST-305)

Practical (Computer based)

(4 Credits)

Max Marks: 75+25\*\*\*

-Practical: 60

-Class Record: 05

-Viva-Vice: 10

\*\*\* Internal Assessment

Time: 4 hrs.

**Note: There will be 4 questions, the candidate will be required to attempt any 03 questions.**

### List of Practicals based on C :

1. Estimation of population mean, total, confidence limits and variance of estimator under simple random sampling.
2. Estimation of population total, population mean and variance of estimator under stratified random sampling.
3. Calculation of optimum and proportional allocation.
4. Comparison of stratified sampling with different types of allocation with unstratified simple random sampling.
5. Comparison of systematic sampling with simple random and stratified random sampling.
6. Estimator of the mean squared error of the product estimator.
7. Estimation of variance in double sampling for stratification.
8. Estimation of gain in precision due to stratification from the results of stratified sample.
9. Ratio estimator for mean and total of population, variance of the estimators.
10. Comparison of ratio estimator with mean per unit estimator under simple random sampling.
11. Comparison of separate and combined ratio estimators under stratified random sampling with mean per unit estimate or under random sampling.
12. Comparison of different types of allocation for ratio estimator under stratified random sampling.
13. Comparison of two ratios.
14. Comparison of regression, ratio and mean per unit estimates from a simple random sample.

## Semester – III Statistics-II

Open Elective  
(OE-309)

### Course Objectives:

This is an introductory course in statistics. Students are introduced to the fundamental concepts involved in using sample data to make inferences about populations. This course is to provide an understanding for the student on statistical concepts to include: tests of hypothesis, sampling distributions, one-way and two-way *ANOVA*. It provides knowledge to perform hypothesis tests on means and proportions for one or two populations for small as well as large sample.

**Course Outcomes:** On successful completion of the course, Students will be able to:

- Understand concepts of sample vs. population.
- Perform basic statistical inference tasks involving various forms of hypothesis test for one and two samples.
- Apply inferential statistical methods via hypothesis testing.
- Analyze the data and use the tests based on t, F, chi square and *ANOVA*.

## Semester – III Statistics-II

Open Elective  
(OE-309)

(2 Credits)  
Max Marks: 35+15\*\*\*  
\*\*\*Internal Assessment  
Time: 3 hrs.

**Note:** There will be ten questions in all i.e. five from each unit. The candidate will be required to attempt five questions selecting atleast two from each unit. The weightage of all the questions will be the same.

### Unit-I

Concept of population and sample, parameter and statistic, need of sampling, types of sampling (definition only), sampling distribution of a statistic, standard error, Statistical hypothesis, null and alternative hypotheses, simple and composite hypotheses, procedure in hypothesis testing, types of errors, power of test and critical region, levels of significance, one and two tailed test, degrees of freedom, Tests of hypothesis-large sample tests: test of hypothesis for single mean, difference of means, proportions, difference of proportions, standard deviation and difference of standard deviations.

### Unit-II

Sampling distributions and their applications: Student - t distributions, F- distribution, Fisher's z – distribution and Chi-square distribution. Simple tests based on t, F, chi square and normal variate z. Analysis of variance: for one-way classification, two-way classification (for fixed effect model only).

### References:

1. Gupta, S.C. & Kapoor, V.K.(2010) : Fundamentals of Mathematical Statistics,  
Sultan Chand and Sons.
2. Gupta, S.C. & Kapoor, V.K.(2014) : Fundamentals of Applied Statistics, Sultan Chand  
and Sons.
3. Goon, A.M., Gupta, M.K(2016) : Fundamentals of Statistics, Vol. II, ed. VI, Word Press &  
Dasgupta, B.

**M.Sc. Statistics Semester – IV**  
**Multivariate Analysis**

**(ST-401)**

**Course Objectives:**

The objective of the course is to introduce several useful multivariate techniques and making strong use of illustrative examples. The course focuses on extensions of univariate techniques to multivariate framework, such as multivariate normal distribution, hypothesis testing and simultaneous confidence intervals. The course will also cover the advance techniques of multivariate such as principal component analysis, Canonical correlation analysis and classification.

**Course Outcomes:**

On completion of this course students will be able to:

- Describe the multivariate analysis tools in relation to univariate tools
- Understand sampling distribution and maximum likelihood estimators of total, partial and multiple correlation coefficients
- Conduct statistical inference by using Hotteling's  $T^2$  and Mahalanobis  $D^2$ -Statistic
- Undertake statistical analyses using appropriate multivariate techniques, which include discriminant, Principal component and Canonical correlation analysis.



**M.Sc. Statistics Semester – IV**  
**Multivariate Analysis**

(ST-401)

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*InternalAssessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

**Unit-I**

Notion of multivariate distribution, multivariate normal distribution of linear combination of normal variates, Marginal and Conditional distributions, Multiple and partial correlation coefficients. Characteristic function of a random vector, characteristic function when the random vector is normally distributed. Moments and semi-invariants of multivariate normal distribution. Estimation of the mean vector and covariance matrix, maximum likelihood estimator of the parameters of multivariate normal distribution.

**Unit-II**

The distribution of the sample mean vector and sample dispersion matrix. Sample correlation coefficient, maximum likelihood estimators of total, partial and multiple correlation coefficients; sampling distribution of simple, partial and multiple correlation coefficients when the corresponding population correlation coefficients are zero. Testing hypotheses of significance of these distributions.

**Unit-III**

Hottelling's  $T^2$  and Mahalanobis  $D^2$ -Statistic; Justification, distribution and uses. The multivariate Behren's Fisher Problem and its solution. Classification Problem: Standards of good classification, Baye's and minimax regions for classification into one of two known multivariate normal populations when the parameters are known and unknown. Fisher's linear discriminator, Anderson's discriminator.

**Unit-IV**

Wishart Distribution: Definition, Characteristic function and properties. Sample generalized variance, asymptotic distribution of sample generalized variances. Principal components in the population, Canonical correlation in the population.

**References:**

1. Anderson, T.W.(1984), : An Introduction to Multivariate Statistical analysis, Second Edition John Wiley.
2. Narayan, C. Giri (2003) : Multivariate Statistical analysis, Marcel Dekker.
3. Srivastava, M.S.& : An introduction to Multivariate Statistics, North Khatri C.G.(1979),Holland.
4. Kshirsagar, A.M.(1972) : Multivariate Analysis, Marcell-Dekher
5. Johnson, R.A (2007): Applied Multivariate Statistical Analysis, PHI Learning & Wichern, D.W
6. Bhuyan, K.C (2005) : Multivariate Analysis and its applications, New Central Book Agency(P) Ltd.

## M.Sc. Statistics Semester – IV

### Linear Estimation & Design of Experiments

(ST-402)

#### Course objective:

This course provides an overview about linear models and design of experiments. To provide orientation of statistics while designing statistical experiments. Exposure to various statistical designs leading to the analysis of variance, eliminating heterogeneity of the data and construction of designs will be provided.

#### Course Outcomes:

On successful completion of this course, students will be able to

Understand the concepts based on Markov models, BLUE and Tests of General Linear hypothesis

Layout and analysis of completely randomized, randomized blocks and Latin-square designs

- Understand the concepts based on Markov models, BLUE and Tests of General Linear hypothesis
- Apply experimental design techniques in real problems.
- Argue the necessity of Factorial experiments and Confounding in Factorial Experiments
- Experimental design to the task of collecting valid and relevant data in order to draw the correct statistical evidence to support a hypothesis.
- Understand the effects of independence or dependence of different factor under study.

**M.Sc. Statistics Semester – IV**  
**Linear Estimation and Design of Experiments** (4 Credits)

(ST-402)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four unit uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

**Unit –I**

Linear estimation : Least Square estimates of regression coefficients, Standard Gauss-Markov models, estimability of parameters, best linear unbiased estimators (BLUE), Method of least squares and Gauss Markov theorem; Variance-Covariance matrix of BLUES, Distributional Properties. Tests of General Linear hypothesis.

**Unit –II**

One-way and two way classifications: ANOVA for Fixed, random and mixed effects Models (One observation per cell). Terminology in experimental designs. Basic principles of design of experiments, General block design and its information matrix, balance and orthogonality, Layout and analysis of completely randomized, randomized blocks and Latin-square designs.

**Unit – III**

Factorial experiments:  $2^2$ -experiment,  $2^3$ -experiment and  $2^n$ -experiment in  $2^k$  blocks per replicate. Confounding in Factorial Experiments: Complete confounding for  $2^2$ -experiment and  $2^3$ -experiment, Partial confounding for  $2^2$ -experiment and  $2^3$ -experiment., Advantages and Disadvantages of Confounding. Split-plot design.

**Unit – IV**

Incomplete Block Design , Balanced incomplete block design, parameters relationship of Balanced incomplete block design, Symmetric Balanced incomplete block design, construction of Balanced incomplete block design by developing initial blocks, analysis of Balanced incomplete block design. Orthogonal Latin squares: construction of orthogonal Latin squares of order 4.

**References:**

1. Searle,S.R.(1997) : Linear Models , John Wiley & sons NewYork.
2. AlopeDey,(1987) : Theory of Block Designs , Wiley EasternLtd.
3. Chakrabarti,M.C(1970) : Mathematics of Design and Analysis of Experiments, Asia Publishing House
4. Joshi, D.D., (1987) : Linear Estimation and Design of Experiments ,Wiley EasternLtd.
5. Das, M.N.andGiri, N(1979) : Design and Analysis of Experiments,WileyEastern. Giri,N. : Analysis of Variance, South AsianPublishers.
6. Montgomery, C.D.(2012) : Design and Analysis of Experiments, Wiley, NewYork.
7. Goon, A.M.,Gupta, M.K.(2013): An Outline of Statistical Theory, Vol. II, World Press. andDasgupta. B.

## **M.Sc. Statistics Semester – IV**

### **Theory of Queues**

**(ST-403 & ST-404) Opt.(i)**

#### **Course Objectives:**

The objective of this course is to introduce the concept of probabilistic tools and concepts which are useful in modeling, such as Markov models and queueing theory. The students also study the various advanced queueing models with their practical utility in communication systems, computer networks, traffic control and other related fields. The queueing models are used to find out the optimum service rate and the number of servers so that the average cost of being in queueing system and the cost of service are minimized.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Deep understanding of the theoretical background of queueing systems.
- Acquire skills in handling situations involving more than one random variables and functions of random variables.
- Understand to analyze the performance of computer systems and queues by applying basic concept of probability techniques and models.
- Understand and compute measures of effectiveness for different queueing systems also apply & extend queueing models to analyze real world systems.

**M.Sc. Statistics Semester – IV**  
**Theory of Queues**

(ST-403& ST-404) Opt.(i)

(4 Credits)  
Max Marks: 75+25\*\*\*  
\*\*\*Internal Assessment  
Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

Unit-I

Queueing system. Components of a queueing system, measures of effectiveness, notations, exponential distribution and its various properties, stochastic processes, definition and examples, Poisson process and its some important properties related to queues. Markov chains and its properties (without proof). Concepts of steady state and transient state, K-Erlang distribution. Birth and death process.

Unit-II

M/M/1 queueing system steady state and time dependent solutions. measures of effectiveness, busy period distribution, 'waiting time distribution, Little's formula. State probability generating function for M/M/1/N queueing system and its steady state probabilities measures of effectiveness, Time dependent solutions of M/M/ $\infty$  queueing system and M/M/ $\infty$  queueing system with time dependent input parameter, measures of effectiveness.

Unit-III

M/M/1 queueing system with phase type service, busy period time distribution, waiting time distribution, Multiple channel queueing system with Poisson input and constant service time (M/D/C), Measures of effectiveness. Erlang service model M/E<sub>k</sub>/1, Erlang arrival model E<sub>k</sub>/M/1.

Unit-IV

Departure point steady state system size probabilities for M/G/1 queueing system, special cases M/E<sub>k</sub>/1 and M/D/1 Pollaczek-Khintchine formula, waiting time, busy period analysis. Arrival point steady state system size probabilities for GI/ M/1 queueing system. Machine interference Model

**References:**

1. Gross, D. & Carl M. Harris (1998) : Fundamental. of queueing theory, John Wiley and Son..
2. Saaty, T.L.(2000): Elements of queueing theory with applications. McGraw Hill Book Company Inc.
3. Allen, A.O.(2010): Probability, Statistics and Queueing Theory with Computer Science Applications, Academic Press
4. Kashyap, B.R.K & Chaudhary, M.L (1988): An Introduction to Queueing Theory, AARKAY Publications, CalcuttsChaudhary, M.L.

**M.Sc. Statistics Semester – IV**  
**Reliability and Renewal Theory**

**(ST-403 & ST-404) Opt.(ii)**

**Course Objectives:**

To introduce the elementary and advanced concepts of reliability and Renewal Theory. This course provides the students the ability to use statistical tools to characterize the reliability and the working knowledge to determine the reliability of various systems. Also, suggest various approaches to enhancing system reliability. This course also provide the students the ability to select appropriate reliability validation methods and renewal processes.

**Course Outcomes:**

On completion of this course students will be able to:

- Describe the basic concepts of reliability and Renewal Theory in real life scenario.
- Understand the appropriate methodologies and tools for enhancing the inherent and actual reliability of components /systems, taking into consideration cost aspects.
- Apply various Reliability and Availability evaluation Techniques for systems having different numbers of components
- Define various Renewal processes and to derive the distribution of the number of renewals.

## M.Sc. Statistics Semester – IV

### Reliability and Renewal Theory

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

(ST-403 & ST-404) Opt.(ii)

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same

#### Unit-I

Concept of reliability , early age failures, wear out failures and chance failures. Derivation of general reliability function failure rate, failure density function and mean time between failures ( MTBF). System reliability evaluation: series system, parallel system, partially redundant system, standby system with perfect switching / imperfect switching. Effect of spare components (identical / non- identical) on the system reliability.

#### Unit-II

Wear out and Component reliability, Combined effect of wear out and chance failures. Reliability of a two component system with single repair facility. Reliability evaluation Techniques : Conditional probability approach , cut set method, approximation evaluation, Deducing the minimal cut sets. Tie set method , connection matrix technique.

#### Unit-III

Availability and Reliability evaluation in Repairable system, evaluation of time dependent probabilities with single repairable component, two repairable components. Evaluating limiting state probabilities with single repairable component, two identical repairable components Matrix multiplication method: reliability evaluation in repairable system, mean time to failure. Stochastic transitional probability matrix method to evaluate MTTF of two components parallel system, two component series system.

#### Unit-IV

General Introduction. The distribution of the number of renewals: The asymptotic distribution of  $N_t$ . The asymptotic normality of  $N_t$  with mean  $t/\mu$  and variance  $t/\mu^3$  The number of renewals in a random time, the renewal function , the asymptotic form of the renewal function. The renewal density, variance of the number of renewals. Backward and forward recurrence times. Limiting distribution of recurrence times.

#### References:

1. Cox D.R. & Miller H.D. (1994) : Theory of Stochastic Processes, Chapman and Hall Ltd.
2. Billinton, R.(1997) : Reliability Evaluation of Engineering systems: Concepts and Techniques Plenum Press New York London.
3. Cox, D.R.(1967) : Renewal Theory, Methuen & Co. Ltd.
4. Medhi, J. (2010): Stochastic Processes New Age International (P)Limited.
5. Igor Bazovsky (1961) : Reliability Theory and Practice, 2nd ed. Prentice Hall.

**M.Sc. Statistics Semester - IV**  
**Machine Learning**

**(ST-403 & ST-404) Opt.(iii)**

**Course Objectives:**

The objective of this course is to introduce the concept of learning patterns from data and develop a strong theoretical foundation for understanding state of the art Machine Learning algorithms. This course is broad in scope and gives the student a holistic understanding of the subject.

**Course Outcomes**

On completion of this course students will be able to:

- Understand basics of machine learning.
- Have in-depth knowledge of supervised learning.
- Understand non-parametric methods along with decision trees.
- Understand about the basics and importance of unsupervised learning and artificial neural networks.



**M.Sc. Statistics Semester - IV**  
**Machine Learning**

(ST-403 & 404) Opt. (iii)

(4 Credits)

Max. Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: - 3 hrs.

**Note:** Total number of questions shall be nine. Question number one will be compulsory and will be consisting of short/objective type questions from complete syllabus. In addition to compulsory first question there shall be four units in the question paper each consisting of two questions. Student will attempt one question from each unit in addition to compulsory question. All questions will carry equal marks.

**Unit – I**

What is Machine Learning, Why Machine Learning is Required, Relation to Artificial Intelligence, Current Applications & Future of Machine Learning in Various Industries, Basic Process of any Machine Learning System, Terminologies used in Machine Learning, Evaluation Metrics in Machine Learning, Machine Learning Categories , Supervised Learning, Unsupervised learning, Reinforcement Learning.

**Unit – II**

Understanding of Supervised Learning with example, Vapnik-Chervonenkis (VC) Dimension, PAC Learning, Regression, Model Selection and Generalization, Dimensions of a Supervised Machine Learning Algorithm, Bayesian Decision Theory, Parametric Methods : Maximum Likelihood Estimation, Regression, Model Selection Procedure, Multivariate Methods: Multivariate Data, Multivariate Classification, Tuning Complexity, Multivariate Regression; Support Vector Machines, Random Forest.

**Unit – III**

Non Parametric Methods: Histogram Estimator, Kernel Estimator, k Nearest Neighbor Estimator, Non Parametric Classification, Condensed Nearest Neighbor, Non Parametric Regression – Smoothing Models, How to Choose Smoothing Parameter.

Decision Trees :Univariate Trees, Classification Trees, Regression Trees, Pruning, Rule Extraction from Trees, Learning Rules from Data, Multivariate Trees.

**Unit – IV**

Unsupervised Machine Learning: k-Means Clustering, Expectation Maximization Algorithm, Supervised Learning after Clustering, Hierarchical Clustering, Choosing the number of Clusters.

Neural Network(NN) : Introduction, Important Concepts in NN, The Perceptron, Training a Perceptron, Learning Boolean Functions, Multilayer Perceptron, MLP as a Universal Approximator, Backpropagation Algorithm, Training Procedures, Tuning the Network Size, Bayesian View of Learning, Dimensionality Reduction, Learning Time.

**References :**

1. Alpaydin E.,(2006): Introduction to Machine Learning, Prentice Hall of India,.
2. Mitchell T. M.,: (1997)Machine Learning, McGraw-Hill,.
3. Bishop C.M., (2016):Pattern Recognition and Machine Learning, Springer,.
4. Hastie, T., Tibshirani R. & (2009): The Elements of Statistical Learning: Data Mining, Inference and Prediction, Springer, 2nd Edition,
5. Murphy K. P., (2012): Machine Learning A Probabilistic Perspective, MIT Press,.
6. Shwartz ShaiShalev & David Shai Ben : Machine Learning – From Theory to Algorithms Cambridge University Press.
7. Marsland, Stephen (, 2009): Machine Learning- An Algorithmic Perspective, CRC Press.

**M.Sc. Statistics Semester - IV**  
**Information theory**

**(ST-403 & ST-404) Opt. (iv)**

**Course Objectives:**

The main purpose of this course is to help students to enhance knowledge of probabilities, entropy, measures of information and coding theory. This course also aims to guide the student through the implications and consequences of fundamental theories and laws of information theory and coding theory with reference to the application in modern communication.

**Course Outcomes:** On completion of this course students will be able to:

- Define measure of information, uncertainty and their properties.
- Relate the joint, conditional, and marginal entropies of variables in terms of their coupled probabilities.
- Define channel capacities and properties using Shannon's Theorems.
- Construct efficient codes for data on imperfect communication channels.

## M.Sc. Statistics Semester - IV

### Information Theory

(4 Credits)

(ST-403 & ST-404) Opt. (iv)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

#### Unit-I

Introduction : communication process, communication system, measure of information, unit of information. Memory less finite scheme: Measure of uncertainty and its properties, sources and binary sources. Measure of information for two dimensional discrete finite probability scheme: conditional entropies, Noise characteristics of a channel, Relations among different entropies.

#### Unit-II

Measure of Mutual information, Shanon's fundamental inequalities, Redundancy, Efficiency and channel capacity, capacity of channel with symmetric noise structures, BSC and BEC, capacity of binary channels, Binary pulse width communication channel, Uniqueness of entropy function.

#### Unit-III

Elements of encoding : separable binary codes, Shannon-Fano encoding, Necessary and sufficient conditions for noiseless coding. Theorem of decodibility, Average length .of encoded messages; Shannon's Binary Encoding.

#### Unit-IV

Fundamental theorem.of discrete noiseless encoding, Huffman's minimum redundancy code, Gilbert-Moore encoding. Error detecting and Error correcting codes, Geometry of binary codes, Hamming's single error correcting code.

#### References:

1. Reza, F.M. (2003): An Introduction to Information Theory, McGrawHill Book:Company Inc.
2. Feinstein, A. (I)(2013) : Foundations of Information Theory, McGraw Hill Book Company Ioc.
3. Kullback, S. (I) (1997): Information Theory and Statistic., John Wiley andSons.
4. Middleton, D. (1996): An Introduction to Statistical CommunicationTheory, McGraw Hill Company

**M.Sc. Statistics Semester – IV**  
**Game Theory**

**(ST-403 & ST-404) Opt. (v)**

**Course Objectives:**

This course introduces students to the basics of game theory and reviews different types of games which are widely used in practice. It also considers the various solution concepts of games and how they can be applied to solve problems occurring in economics and other scientific disciplines. The course provides a strong foundation for those students wishing to study more advanced level courses in game theory.

**Course Outcomes:**

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

- Discuss the theory which underlies rectangular games and fundamental theorem of rectangular games.
- Understand the properties of optimal strategies and method of approximating the value of a game.
- Possess a set of intermediate level game-theoretic skills which can be applied in real world contexts.
- Elucidate the games with perfect and infinitely many strategies potential .

**M.Sc. Statistics Semester – IV**  
**Game Theory**

(ST-403 & ST-404) Opt.(v)

**(4 Credits)**  
**Max Marks: 75+25\*\*\***  
**\*\*\*Internal Assessment**  
**Time: 3 hrs.**

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four units uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

**Unit-I**

Rectangular games, rectangular games with saddle points. Fundamental theorem of rectangular games: Mixed strategies, Geometrical background, Proof of the fundamental theorem for arbitrary rectangular games.

**Unit-II**

Properties of optimal strategies. Relations of dominance. A graphical method of solution. Applications of linear programming. The solution of a rectangular game. A method of approximating the value of a game.

**Unit-III**

Game in extensive form. Normal form and extensive form. Graphical representation information sets. Chance moves. Games with more than two players. Restrictions on information sets. General theory of games in extensive form.

**Unit-IV**

General definition of finite games with perfect information equilibrium points. Games with perfect recall and behaviour strategies. Games with infinitely many strategies. The fundamental theorem for continuous games.

**References:**

1. Mackinsey, J.G.C.(2003): Introduction to the theory of games McGraw Hill Book Company. Inc..New Delhi, Toronto and London.
2. Churchman, C.W.(1957) : Introduction to Operations Research John Wiley & Sons New York.
- 3 B.S. Goel, S.K. Mittal, (2014).Operations Research, Pragater Prekshlen, John & Sons.

## **M.Sc. Statistics Semester – IV**

### **Actuarial Statistics**

**(ST-403 & ST-404) Opt. (vi)**

#### **Course Objectives:**

This course investigates modern actuarial modeling and examines the basic techniques used in actuarial analysis. The aim of this course is to provide the students a firm mathematical and statistical background so that they can apply mathematical and statistical models to assess risk factors and to apply stochastic models appropriate to the representation of the risk process.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Able to recognize the basic concepts of mortality rates and other indices
- Understand the concept of different models of population dynamics and Industrial assurance.
- Apply the typical long-tailed distributions representing claim size and those representing claim numbers
- Use statistical models to analyze the risk factors for categories of policy holders and apply appropriate mathematical methods to get solutions for some problems in risk theory.

**M.Sc. Statistics Semester – IV**  
**Actuarial Statistics**

(ST-403& ST-404) Opt. (vi)

(4 Credits)

Max Marks: 75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four unit uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

Unit-I

Concepts of mortality rates and other indices, construction of mortality table from graduated data, determination and use of the functions in mortality table, graph of force of mortality, laws of mortality, mortality funds, Sources and collection of data for the continuous mortality investigation.

Unit-II

Models of population dynamics: Lotka' theory. Relationship between the number of births and the number of women in the population. Population with unvarying age distribution. Nature of reserve, prospective and retrospective reserves, fractional premiums and fractional durations, modified reserves, (continuous reserves, surrender values and paid up policies, Industrial assurance; children's. deferred assurances, Joint life and last survivorship.

Unit-III

Pure endowments, Life Annuities; Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due. Accumulations, Assurances, family income benefits, capital sums on retirement and death.

Unit-IV

Widows pensions, Sickness benefits, disability benefits. Orphan's benefits, Benefits dependent on marriage. Contingent probabilities, contingent assurances, reversionary annuities, multiple-decrement table, forces of decrement, construction of multiple decrement table.

1. King, G. (2011) : Institute of actuaries text book of part II second ed. Charles and Edwin Layton London.
2. Jordan, C.W.(1991) Jr : Life Contingencies, second edition, Chicago Society of Actuaries.
3. Neill, A. (1977) : Life Contingencies, Heinemann, London
4. Donald, DWA (2016) : Compound interest and annuities. Heinemann London

## **M.Sc. Statistics Semester – IV**

### **Official Statistics**

**(ST-403& ST-404) Opt.(vii)**

#### **Course Objectives:**

The course aims at developing an awareness of the use of Official Statistics. The objective of this course is to make the students familiar with Present official Statistical Systems in India and its Roles & Functions.

#### **Course Outcomes:**

On completion of this course students will be able to:

- Understand the concept of Indian and International Statistical Systems.
- Deep understanding of population growth in Developed and Developing Countries.
- Deal with System of Collection of Agricultural Statistics.
- Know the responsibilities of various Agencies for data collection like CSO, NSSO and office of Registrar General.



**M.Sc. Statistics Semester – IV**  
**Official Statistics**

(ST-403& ST-404) Opt. (vii)

(4 Credits)

Max Marks:75+25\*\*\*

\*\*\*Internal Assessment

Time: 3 hrs.

**Note:** There will be nine questions in all. Question No.1 will be compulsory covering whole of the syllabus and comprising short answer type questions. Rest of the eight questions will be set from the four unit uniformly i.e. two from each unit. The candidate will be required to attempt five questions in all one from each unit and the compulsory one. The weightage of all the questions will be the same.

**Unit-I**

Introduction To Indian and International Statistical Systems. Present official Statistical Systems In India, Role, Functions and Activates of Central and State Organization. Organizations of Large Scale Sample Surveys Methods of Collection of official Statistics, Their Reliability and Imitations.

**Unit-II**

General and Special Data Dissemination Systems, Population Growth in Developed and Developing Countries.Evaluation of Performance of Family Welfare Programs Projection of Labor force and Manpower.Scope and Content O Population of Census of India.

**Unit-III**

System of Collection of Agricultural Statistics.Crop forecasting and Estimation.Productivity, Fragmentation of Holdings, Support Prices Buffer Stock.Principle Publications Containing SuchStatistics.

**Unit-IV**

Statistics Related To Industries, Balance of Payment, Cost of Living, Inflation, Educational and Other Social Statistics. Various Agencies Responsible for The Data Collection CSO, NSSO, office of Registrar General.

**References:**

1. Basic Statistics relating to the Indian Economy (CSO)1990.
2. Statistical system in India (CSO)1975.
3. Guide to official Statistics (CSO)1999.
4. Principles and accommodation of National Populations CensusUNESCO.
5. Panse, V.G., Estimation of Crop Fields(FAO).

## **M.Sc. Statistics Semester – IV**

### **Practical (Calculator and SPSS/SYSTAT based)**

**(ST-405)**

**Course Objectives:** The objective of the course is to provide practical knowledge about the concepts based on Multivariate Analysis and Design of Experiment. This course also focuses on hands-on training through SPSS and SYSTAT to analyze different problems based on experimental designs.

**Course Outcomes:** On completion of this course students will be able to:

- Perform exploratory analysis of multivariate data using SPSS and SYSTAT.
- Conduct statistical inference about multivariate means including hypothesis testing and different types of confidence intervals estimation;
- Understand to design and conduct experiments, as well as analyze and interpret data.
- Understand to check the affects of different factors under study and analyze Split-plot design & BIBD.

**M.Sc. Statistics Semester – IV**  
**Practical (Calculator and SPSS/SYSTAT based)**

(ST-405)

(4 Credits)

Max Marks: 75+25\*\*\*

-Practical : 60

-Class Record : 05

-Viva-Vice : 10

\*\*\* Internal Assessment

Time: 4 hrs.

**Note: There will be 4 questions; the candidate will be required to attempt any 3 questions.**

**List of Practicals:**

1. Estimating parameters of multinormal distribution.
2. Calculation of multiple and partial correlation coefficients.
3. Estimating the parameters of conditional distribution.
4. Test based on total, partial and multiple correlations.
5. Test based on Hotelling -  $T^2$  and Mahalanobis -  $D^2$  Statistics.
6. Fisher's linear discriminant function.
7. Calculation of principal components.
8. Analysis of three basic designs- Basic analysis and splitting of treatment S. S. for different contrasts.
9. Analysis of  $2^2$  – factorial experiment.
10. Analysis of  $2^3$  – factorial experiment.
11. Analysis of completely confounded factorial experiment.
12. Analysis of partially confounded factorial experiment.
13. Analysis of split plot design.
14. Analysis of BIB Design.