Learning Outcomes-based Curriculum Framework (LOCF) for Post-graduate Programme

Name of the Programme:

M.Sc. Statistics

(Syllabus effective from 2020 Admission onwards)

UNIVERSITY OF KERALA

Syllabus for M.Sc. Statistics

Programme Specific Outcomes (PSO) for M.Sc. Statistics

PSO1	Expertise in the field of statistical theory and its applications
PSO2	Expertise to take up responsibilities as efficient Statisticians/Statistical Officers/Research Officers/ Statistical Analytics
PSO3	Expertise on data analysis or use of statistical techniques
PSO4	Awareness on recent developments in statistical theory and practice

Structure of the Programme

Sem. No.	Course code	Name of the Course	Number of Credits
I	Core Courses (CC) STA-CC-511 STA-CC-512 STA-CC-513 STA-CC-514	 Measure Theory Mathematical Methods Distribution Theory Statistical Computing	 4 4 4 4
II	Core Courses(CC) STA-CC-521 STA-CC-522 STA-CC-523 STA-CC-524 STA-CC-525	 Sampling Theory Applied Statistics Multivariate Analysis Probability Theory Practical 1	 4 4 4 4 2
III	Core Courses (CC) STA- CC-531 STA-CC-532 STA-CC-533	 Stochastic Processes Estimation Testing of Hypotheses	 4 4 4
	Discipline Specific Electives (DE) STA-DE-534(i) STA-DE-534(ii) STA-DE-534(iii)	 Statistical Quality Control and Reliability Modeling Advanced Probability Theory Data Mining	 4 4 4
IV	Core Courses (CC) STA-CC-541 STA-CC-542 STA-CC-543	 Nonparametric Methods Design and Analysis of Experiments Practical 2	 4 4 2

	Discipline Specific Electives (DE) STA-DE-544(i) STA-DE-544(ii) STA-DE-544(iii) STA-DE-545(i) STA-DE-545(ii) STA-DE-545(iii) Dissertation STA-CC-546	 Operations Research Bayesian Inference Order Statistics Regression Analysis and Econometric Methods Actuarial Statistics Biostatistics Dissertation	 4 4 4 4 4 4 4
Generic Courses (GC)			
II	STA-GC-521	Elements of Probability Theory	2
III	STA-GC-531	Elementary Statistical Methods	2

STA – Representing Department of Statistics .CC, DE and GC –Representing Core Courses, Discipline Specific elective and Generic Courses, respectively. First numerical number 5 representing 5th level of Education. Middle numerical number 1,2,3 and 4 representing Semester 1,2,3 and 4 respectively. Last numerical number 1,2,3 etc. representing Course Numbers.

SEMESTER : I
COURSE CODE : STA-CC-511
COURSE TITLE : MEASURE THEORY
CREDITS : 4

COURSE OUTCOMES

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

CO1. Explain classes of open and closed sets of R.
CO2. To understand the concept of semi-ring, ring, field, sigma-ring, sigma-field and monotone class with the help of examples.
CO3. Explain the concept of additive and totally additive set functions with the help of certain examples.
CO4. To be familiar with outer measure and counting measure.
CO5. To understand the concept of Lebesgue measure.
CO6. Identify the properties of measurable functions.
CO7. Distinguish between Lebesgue integral and Riemann integral.
CO8. State and prove monotone convergence theorem and Lebesgue dominated convergence theorem.
CO9. Explain the concept of convergence in a sequence of measurable functions.
CO10. To be familiar with the concept of absolute continuity and singularity.
CO11. State and prove Radon-Nikodym theorem.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy Level**
Module 1.	M01. Explain and exemplify the concepts of Boral field M02. Prove that any finite field is also a σ –field. M03. Articulate the concept of classes of sets.	Understand Remember Understand
Module: 2	M01. State and prove Hahn-Jordan decomposition theorem. M02. Articulate the basic concept of measure. M03. Give the examples of measure like length, area and volume.	Remember Understand Apply
Module 3	M01. Define and exemplify measurable function. M02. Explain various result associated with measurable functions. M03. To be familiar with complete measure.	Understand Remember Understand

	M04. Examine various properties of a probability measure.	Analysis
Module 4	M01. To be familiar with the definition and properties of integral. M02. Explain Lebesgue Stieltjes measure. M03. State and prove Fatou's lemma.	Understand Understand Remember
Module 5	M01. Describe the concept of sequence of measurable functions. M02. Introduce the concept of product spaces and product measures. M03. State and prove Fubini's theorem.	Apply Understand Remember
Module 6.	M01. State and prove Lebesgue decomposition theorem. M02. Articulate the concept of functions of bounded variations. M03. Examine the properties of Radon-Nikodym derivative	Remember Understand Analysis

COURSE CONTENT

MODULE I : Classes of open and closed sets of R, Classes of sets. Monotone class: semi-ring, ring, sigma- ring, field and sigma -field, sigma-field generated by a class of sets. Borel field.

MODULE II: Additive and countably additive set functions, Hahn – Jordan decomposition theorem. Outer measure, measure and counting measure, examples of measure like length, area and volume.

MODULE III : Lebesgue measures, Lebesgue – Stieltjes measure, Measurable functions and properties.

MODULE IV : General theory of integral and its properties, Lebesgue and Riemann integrals, Lebesue– Stieltjes integral. Theorems on integrals: Fatou's Lemma, Monotone convergence and Lebesgue dominated convergence theorems.

MODULE V : Sequences of measurable functions. Convergence in measure, Convergence in mean, Convergence a.e, almost uniform convergence and convergence in pth mean. Product spaces and product measures, Fubini's theorem.

MODULE VI : Absolute continuity and singularity, Lebesgue decomposition and Radon – Nikodym theorem, properties of Radon – Nikodym derivative, Functions of bounded variation.

REFERENCES

- Kingman and Taylor, S.J. (1977): Introduction to Measure and Probability, Cambridge University Press, Cambridge.
- Roydon, H. L. (1968) : Real Analysis, Macmillan, New York.
- Rudin, W.(1970) : Real and Complex Analysis, McGraw Hill Book Co., New York.

SEMESTER : I
COURSE CODE : STA-CC-512
COURSE TITLE : MATHEMATICAL METHODS
CREDITS : 4

COURSE OUTCOMES

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

CO1. Have a clear understanding of Metric space - Metric in Rn.
CO2. Explain the concept of Cauchy sequence, completeness, compactness and connectedness with the help of examples.
CO3. To have a clear knowledge on differentiability of a function.
CO4. State and prove generalized mean value theorem.
CO5. Describe the properties of Riemann- integral.
CO6. State and prove mean value theorem of integral calculus.
CO7. Identify the applications of multiple integrals.
CO8. To achieve ideas on vector space, subspaces, independence of vectors, basis and dimension.
CO9. State and prove Cayley-Hamilton theorem.
CO10. Establish the relation between algebraic and geometric multiplicity.
CO11. To achieve ideas on quadratic forms and reduction of quadratic forms and gets an ability for solving problems in these areas.
CO12. Define Moore-Penrose g-inverse and derive its properties.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy Level**
Module 1.	M01. To be familiar with the idea of open and closed set. M02. Find the limit point of a sequence. M03. State and prove Hein-Boral theorem.	Understand Evaluate Remember
Module: 2	M01. Find the limit and continuity of a given function. M02. Find the conditional maximum and minimum of a given function. M03. Verify generalized mean value theorem to a given function.	Apply Apply Analysis
Module 3	M01. Write the Riemann integral of the given function.	Apply

	M02. State and prove Fubini's theorem.	Remember
Module 4	M01. Find the rank of a given matrix. M02. Understand the concept of determinants and its properties. M03. Solve the system of linear equations.	Evaluate Understand Apply
Module 5	M01. Determine the Eigen values and Eigen vectors of the given matrix M02. Obtain the diagonal form and triangular form of a given matrix. M03. Write down the spectral decomposition of the given matrix	Evaluate Apply Evaluate
Module 6.	M01. Find the nature of the quadratic form. M02. Articulate the concept of generalized inverse. M03. Obtain the g-inverse and Moore- Penrose g-inverse of the given matrix.	Analysis Understand Apply.

COURSE CONTENT:

MODULE I: Metric space-Metric in Rn, open set, closed set, limit point of a set, sequence in Rn-Cauchy sequence, completeness, compactness, connectedness, Hein-Boral theorem.

MODULE II: Functions in Rn, limit and continuity, differentiability, extreme values of a function (more than one variable), conditional maximum and minimum, generalized mean value theorem.

MODULE III: Reimann integrals, properties of Reimann Integrals, mean value theorem of integral calculus, multiple integrals, Fubini's theorem, Change of order of integration, transformation of variables.

MODULE IV : Vector space and subspaces, independence of vectors, basis and dimensions. Matrices and determinants, rank of a matrix, null space, and nullity, partitioned matrices, Linear transformations, matrix representation of linear transforms. Solution of system of linear equations.

MODULE V: Eigen values and eigen vectors, algebraic and geometric multiplicity of eigen values, Cayley-Hamilton theorem, Spectral decomposition of Matrices, canonical forms, diagonal form, triangular form, Jordan form.

MODULE VI: Quadratic forms, reduction of quadratic forms, generalized inverse, Moore-Penrose inverse, Jacobian of transformation, derivative of a function with respect to a vector, with respect a matrix.

REFERENCES

Dissertation

- Apostol,T.M.(1987): Mathematical Analysis, 2nd edn, Narosa Publishing House, New Delhi.
- Goldberg,R.R.(1970): Methods of Real Analysis, Oxford & IBH publishing Co. (P) Ltd. NewDelhi.
- Graybill,A and Belmont, C.A.(1983): Matrices with Applications in Statistics, II Edition, John Wiley, New York.
- Pringle,R.M. and Rayner,A. A(1971): Generalised Inverse of Matrices with Application to
Statistics, Griffin, London.
- Rao,C.R (1973): Linear Statistical Inference and its Applications, Wiley Eastern, New York.

SEMESTER **:** I
COURSE CODE **:** STA-CC-513
COURSE TITLE **:** DISTRIBUTION THEORY
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. understand the properties of probability density functions and cumulative distribution functions.

CO2. Define expectation, and be introduced to its important linearity property.

CO3. Calculate raw moments and central moments, including their special cases, the mean and variance.

CO4. Calculate the moment generating function, and appreciate its link to moments.

CO5. Realize the difference between discrete and continuous probability distributions.

CO6. Finding conditional and marginal distributions from a bivariate probability distribution.

CO7. Apply transformation of variable technique for finding the distribution of functions of random variables and solve related problems

CO8. Explains different sampling distributions and find expressions for their probability density function.

CO9. Explain the concept of order statistics and solving problems related to it

CO10. Distinguish between partial and multiple correlation and the concept of empirical distribution function.

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy level
Module 1	M01. Explains the basic concepts of pgf, mgf and characteristic functions	Understand
	M02. Examine various types of discrete and continuous distributions and articulate their properties	Analysis
	M30. Examine the various properties of probability distribution.	Analysis
	M04. Solving problems related to several distributions	Apply
Module 2	M01. Finding the joint, marginal and conditional pdf of a bivariate distribution	Understand
	M02. Articulate the various concepts of Conditional expectation and conditional variance	Analysis
	M03. Explains the concept of pgf, mgf and independence of a bivariate random vector	Remember
	M04. Articulate Multinomial and bivariate normal distributions and their properties in detail	Apply
Module 3	M01. Apply transformation of variable technique for finding the distribution of functions of random variables and solve related problems	Apply
	M02. Derive the distributions of sum, product and ratios of random variables	Analysis
Module 4	M01. Explain the concept of order statistics	Understand
	M02. Find the joint distribution of two order statistics	Evaluate
	M03. Calculate Distribution of functions of two order statistics	Apply
Module 5	M01. Explains different sampling distributions	Understand
	M02. Find expressions for probability density function of sampling distribution	Apply
Module 6	M01. Distinguish between partial and multiple correlation coefficient	Understand
	M02. Finding the Distribution of empirical distribution function	Evaluate
	M03. Explain the concept of generalized standard deviation.	Remember

COURSE CONTENT

MODULE I : Basic concepts in distribution theory : p.g.f., m.g.f., and characteristic function.

Univariate distributions: Binomial, Negative Binomial, Poisson, Hyper geometric, Geometric, Beta, Gamma, Normal, Log-Normal, Pareto, Weibull, Cauchy. Laplace, Logistic, Log-logistic. Rayleigh and Generalized exponential distributions.

MODULE II : Bivariate distributions: Joint, conditional and marginal distributions. Conditional expectation, conditional variance. Independence, p.g.f. and m.g.f. of bivariate random vector. Multinomial and bivariate normal distributions and their properties. Compound, Truncated and mixture distributions.

MODULE III : Functions of random variables and their distributions using transformation of variable technique: Distributions of sum, product and ratios of random variables.

MODULE IV : Order statistics: Distribution of order statistic, Joint distribution of two order statistics, Distribution of functions of two order statistics.

MODULE V : Sampling distributions: Chi-square, t distribution, and F distributions (both central and non-central) and their applications.

MODULE VI : Empirical distribution; Distribution of empirical distribution function. Correlation and regression ; simple partial and multiple correlation coefficients. Generalized standard deviation.

REFERENCES

- Anderson,T.W.(1984) Introduction to Multivariate Statistical Analysis, Macmillan Publishing Company.
- Fisz,M (1963) Probability Theory and Mathematical Statistics, 3rd Edition, John Wiley.
- Hogg,R.V. and Craig ,A.T.(1989) Introduction to Mathematical Statistics, Macmillan Publishing Company
- Johnson ,N.L. and Kotz,S. (1969) Distributions in Statistics; Discrete distributions. John Wiley and Sons ,New York.
- Johnson ,N.L. . Kotz,S. and Balakrishnan, N (1994)Continuous Univariate Distributions -1 ,2nd Edition John Wiley and Sons ,New York.
- Johnson ,N.L. . and Kotz,S. (1995) Continuous Univariate Distributions -2 ,2nd Edition, John Wiley and Sons ,New York..
- Rohatgi,V.K.(1990) An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd.

SEMESTER : I
COURSE CODE : STA-CC-514
COURSE TITLE : STATISTICAL COMPUTING
CREDITS : 4

COURSE OUTCOMES

After completion of this course the students will be able to

C01.Define the basic concepts of R software and R packages
C02.Describe various concepts required for developing the R Language
C03.Build our own new functions in R
C04.Illustrate different R-Graphics facilities
C05.Perform programming of different statistical methods and procedures
C06.Interpret real life situations by using the data generated using random number generation.

MODULE OUTCOMES

Sl. No.	Outcomes On Completion of each module, Students should be able to:	Taxonomy level
Module 1.	M01.Define basic concepts of statistical software R such as Basic operations in R, Mathematical functions used in R, Assign values to variables etc. M02.Demonstrate the important data structures such as arrays, matrix, data frames, Class function etc. M03. Illustrate using help facilities in R M04. Summarize an overview of R packages	Remember Apply Apply Understand
Module.2	M01.Design an overview of the R Language such as Expressions, Objects, Symbols, Functions, Special Values, R Syntax- Constants, Numeric vectors, Character vectors, Symbols, Operators, Order of operations, Assignments, Expressions. M03. Demonstrate the use of control Structures- Conditional Statements, Loops, Accessing data Structures, M04. Illustrate the use of R Objects such as Vectors, Lists, Matrices, Arrays, Factors, Data Frames, Formulas, Time series.	Create Apply Apply
Module.3	M01.Describe the use of Functions- The function keyword, Arguments, Return values, Functions as arguments, properties of functions M02. Demonstrate the use of writing functions in R. M03.Perform working with data – Entering data within R, Importing data from external files, Exporting data, Combining data sets, Merging data.	Understand Apply Apply

Module 4	M01. Demonstrate the use of R-Graphics: An overview of R graphics, Scatterplots, Bar charts, Histogram, Pie charts. M02. Illustrate the use of Plotting distributions, Plotting time series, Box plots, Stem and lead plot,Q-Q plots. M03. Summarize the use of Graphical parameters, Basic graphic functions. M04. Demonstrate drawing of mathematical functions, Logarithmic functions, Trigonometric functions, polynomial functions.	Apply Apply Understand Apply
Module 5	M01. Develop programming of basic statistical methods and procedures such as Descriptive Statistics, Graphical representation of data, Measures of Central tendency, Measures of dispersion, Measures of skewenss and kurtosis M02. Choose representative samples M03.Evaluation of different probability distributions, Fitting of probability distributions - Binomial, Poisson, Normal. M04. Analyze statistical inference using R- Plots to check normality, Hypothesis testing – Parametric and non-parametric tests concerning means, Testing proportions of one sample and two samples. One way ANOVA and its nonparametric version. Goodness of fit tests, M05. Illustrate the concept of simple correlation and regression.	Create Evaluate Evaluate Analyze Analyze
Module 6	M01. Describe general techniques for simulating continuous random variables - Inverse transformation method, acceptance rejection method. M02. Perform techniques for simulating continuous random variables – Uniform, Exponential, Cauchy, Normal, Gamma, Beta distributions. M03. Perform simulating from discrete distributions- Binomial, Poisson, Geometric distribution.	Understand Apply Apply

COURSE CONTENT

MODULE I: Introduction to the statistical software R, Basic operations in R, Mathematical functions used in R, Assign values to variables, Introduction to data structures - arrays, matrix, data frames. Class function, Getting help, An overview of R packages

MODULE II: An overview of the R Language- Expressions, Objects, Symbols, Functions, Special Values. R Syntax- Constants, Numeric vectors, Character vectors, Symbols, Operators, Order of operations, Assignments, Expressions, Control Structures- Conditional Statements,

Loops, Accessing data Structures, R Objects- Vectors, Lists, Matrices, Arrays, Factors, Data Frames, Formulas, Time series.

MODULE III: Functions- The function keyword, Arguments, Return values, Functions as arguments, properties of functions, Writing functions in R. Working with data – Entering data within R, Importing data from external files, Exporting data, Combining data sets, Merging data.

MODULE IV: R-Graphics: Graphics- An overview of R graphics, Scatterplots, Bar charts, Histogram, Pie charts, Plotting distributions, Plotting time series, Box plots, Stem and lead plot, Q-Q plots, Graphical parameters, Basic graphic functions, Drawing- mathematical functions, Logarithmic functions, Trigonometric functions, polynomial functions.

MODULE V: Programming of statistical methods and procedures: Descriptive Statistics, Graphical representation of data, Measures of Central tendency, Measures of dispersion, Measures of skewenss and kurtosis, Selection of representative samples, Computations of different probability distributions, Fitting of probability distributions - Binomial, Poisson, Normal. Statistical inference using R- Plots to check normality, Hypothesis testing – Parametric and non-parametric tests concerning means, Testing proportions of one sample and two samples. One way ANOVA and its nonparametric version. Goodness of fit tests, Simple correlation and regression.

MODULE VI: Random variable generation: General techniques for simulating continuous random variables - Inverse transformation method, acceptance rejection method. Techniques for simulating continuous random variables – Uniform, Exponential, Cauchy, Normal, Gamma, Beta distributions. Simulating from discrete distributions- Binomial, Poisson, Geometric distribution.

REFERENCES

- Everitt, B.S. and Hothorn T. (2010) A Handbook of Statistical Analysis Using R, Second Edition, CRC Press.
- Joseph Adler (2011) R in a Nutshell, Second Edition, Shroff Publishers and Distributors Pvt. Ltd.
- Michael J. Crawley (2013) The R book, Second Edition, John Wiley & Sons Ltd.
- Rubinstein, R.Y. (1981) Simulation and Monte Carlo Methods, Wiley.

SEMESTER **:** II
COURSE CODE **:** STA-CC-521
COURSE TITLE **:** SAMPLING THEORY
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Understand the principles underlying sampling as a means of making inferences about a population.

CO2. Collect data from a smaller part of a large group so that the students can able to learn something about the larger group.

CO3. understand the difference between randomization theory and model based analysis.

CO4. understand the concepts of bias and sampling variability and strategies for reducing these.

CO5. Analyse data from multi-stage surveys.

CO6. have an appreciation of the practical issues arising in sampling studies.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy level**
Module 1	M01. Distinguish between ordered and unordered sampling method M02. Use various procedures of selecting samples from the population M30. Explain method of selecting samples using simple random sampling. M04. Articulate the estimation of population mean, total and proportion and hence the estimation of the standard error. M05. Explain determination of sample size and confidence interval	Understand Apply Evaluate Apply Evaluate
Module 2	M01. Explain PPS sampling and articulate to selection procedures using PPS with and without replacement M02. Find methods to estimate population mean, total and variance with respect to PPS sampling M03. Apply various selection procedures for selecting samples using PPS	Evaluate Apply Apply
Module 3	M01. Explain the purpose of stratification M02. Explain stratified random sampling M03. Examine the various properties of stratified sampling M04. Explain the concept of double sampling M05. Discuss various allocation procedures	Evaluate Understand Evaluate Understand Analysis

Module 4	M01. Explain systematic sampling M02. Distinguish between single start linear systematic sampling and multiple start linear systematic sampling M03. Describe the comparison of simple random sample, systematic sample and stratified sample for a population with linear trend	Understand Evaluate Understand
Module 5	M01. Distinguish between ratio and regression estimators M02. Explain various properties of ratio and regression estimators M03. Discuss ratio and regression estimator for stratified population	Understand Apply Analysis
Module 6	M01. Explain cluster sampling. M02. Distinguish between clusters of equal and unequal sizes. M03. Describe the two-stage cluster sampling of equal size and unequal size.	Understand Remember Evaluate

COURSE CONTENT

MODULE I: Ordered and unordered sampling designs, Probability sampling. Simple random sampling with replacement and without replacement. Procedures of selection, Estimation of population mean, total, proportion and variance. Estimation of standard errors of these estimators. Confidence intervals. Determination of sample size. Quota sampling and Snowball sampling.

MODULE II: Sampling with varying probabilities: Probability proportional to size (PPS) sampling, Procedure of selecting a PPS sample with and without replacement. Estimation of population mean, total and variance in PPS sampling with replacement. Estimated standard error of estimator of population mean and total. Estimation of population mean in PPS sampling without replacement. Des Raj ordered estimator, Murthy's unordered estimator, Horvitz-Thompson estimator and their estimated standard errors .Yates –Grundy estimator, Midzuno-Sen scheme of sampling, IPPS sampling.

MODULE III: Stratified random sampling: Purpose of stratification, Estimation of population mean and its variance, Various methods of allocation, comparison with unstratified simple random sampling, Estimation of population mean with post-stratification, Effect of using inaccurate stratum size, concept of double sampling and its applications in stratified random sampling when strata sizes are unknown and for Neyman method of allocation, Estimation with stratified PPS sample.

MODULE IV: Systematic sampling; single start linear systematic sampling and multiple start systematic sampling, Circular systematic sampling, selection procedures. Advantages and disadvantages, Estimation of population mean and its variance, Comparison of systematic sampling with simple random sampling, Comparison of systematic sample, SRS and stratified random sample for a population with linear trend.

MODULE V: Estimation of population mean using auxiliary information: Ratio estimator and its properties . First order expression of bias, mean square error and comparison with simple arithmetic mean estimator. Optimum property of ratio estimator. Sampling schemes that provide unbiased ratio estimator. Hartley-Ross unbiased ratio type estimator. Confidence interval of population ratio. Ratio estimator with double sampling. Optimum procedure with cost consideration. Separate and combined ratio estimator for stratified population. Regression estimator and its properties First order expression of bias, mean square error. Comparison with simple arithmetic mean estimator and ratio estimator. Optimum property . First order expression of bias, mean square error and comparison with simple arithmetic mean estimator. Optimum property. Regression estimator with double sampling. Separate and combined regression estimators.

MODULE VI: Cluster sampling with equal and unequal clusters. Estimators of population mean and their estimated standard errors. Relative efficiency of cluster as unit of sampling compared to a single element as unit of sampling. Two stage sampling: Two stage sampling with equal first stage units-estimator of population mean, its standard error and its estimator. Two stage sampling with unequal first stage units-estimators of population mean and their properties. Estimation of standard error of estimators of population mean. Two stage sampling with equal first stage units and sampling is done according to PPS at the first stage and simple random sampling at the second stage. Estimation of the population mean and its variance. Non sampling errors, Various factors, methods of reducing non-response.

REFERENCES

- Cochran , W.G. (1977). Sampling Techniques, Wiley Eastern Ltd.
- Murthy, M. N. (1967). Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
- Singh, D. and Chaudhary, F.S. (1986). Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd.
- Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). Sampling Theory of Surveys With Applications, Indian Society of Agricultural Statistics, New Delhi.

SEMESTER **:** II
COURSE CODE **:** STA-CC-522
COURSE TITLE **:** APPLIED STATISTICS
CREDITS **:** 4

After completion of this course the students will be able to

COURSE OUTCOMES

C01. Generate different components of a time series data
C02. List the important terms of stationary time series
C03. Choose an appropriate model for time series data using the concept of linear time series models
C04. Analyze the prices of different commodities using the concept of Index Numbers
C05. Predict the vital events of humans such as mortality, fertility, longevity etc. using the concept of vital Statistics
C06. Describe the official Statistics system of India and world

MODULE OUTCOMES

Sl.No.	Outcomes On Completion of each module, Students should be able to:	Taxonomy level
Module 1.	M01. Constructs the decomposition of a Time Series M02.Evaluates the secular trend of a time series using methods like method of fitting mathematical curves, Method of moving averages M03. Evaluates the Seasonal fluctuations of time series using Method of simple Averages, Ratio to trend method, Ratio to Moving average method and Link relative method	Applying Evaluating Evaluating
Module.2	M01: Define stationary time series M02:Summarize General linear process and its basic terms like Auto covariance, Auto correlation and their properties, Auto covariance generating function M03: Develop Stationarity and invertibility conditions M04: Demonstrate Exponential and moving average smoothing, Holt-winter smoothing.	Remember Understand Create Apply
Module.3	M01: Evaluate the Stationarity conditions, Autocorrelation function of Autoregressive processes M02:Develope Yule Walker estimation for AR processes and Partial autocorrelation function M03:Generate Invertibility conditions, Autocorrelation function and Partial autocorrelation function of moving average process	Evaluate Create Create
Module 4	M01. Develop the problem of Index Numbers, Calculation of the Indexes Ratio of simple aggregates, Ratio of weighted aggregates, Choice of a base period, fixed base and chain base methods M02.List the advantages and disadvantages, Errors in Index Number Formulae-Formula error, Sampling error and Homogeneity error. M03.Summarize the Different Tests of a good Index Number-	Create Remember Understand

	Unit test,Time Reversal test, Factor reversal test and circular test. Cost of living Index Number.	
Module 5	M01. Explain different measures of Mortality-Crude death rate, Specific death rate. Adjusted Measures of Mortality-Direct method of adjusting, Indirect method of adjusting. M02.Perform calculation of life-tables, Force of Mortality, Abridged life table, Uses of life table. M03. Explain different measures of Fertility- Crude birth rate, General fertility rate, Age specific fertility rate, Total fertility rate. M04.Design measurement of population growth- Crude rate of natural increase, Gross reproduction rate, Net reproduction rate.	Understand Apply Understand Create
Module 6	M01. Discuss Indian Statistical System, International Statistical System M02.Outline Functions and Activities of Ministries of Statistics and Programme Implementation and Central Statistical Organization M03.Demonstarte the working of Annual survey of industries, Agricultural census in India, National Sample Survey Organization, Population Census, Introduction to system of National Accounts.	Understand Remember Apply

COURSE CONTENT

MODULE I: Time Series Analysis: Decomposition of a Time Series, Measurement of Secular Trend - method of fitting mathematical curves, Method of moving averages, Merits and demerits of each methods, Measurement of Seasonal Fluctuations- Method of simple Averages, Ratio to trend method, Ratio to Moving average method, Link relative method, Merits and demerits of each methods.

MODULE II: Time series as a discrete parameter stochastic processes, stationary time series: General linear process, Auto covariance, Auto correlation and their properties, Auto covariance generating function, Stationarity and invertibility conditions, Exponential and moving average smoothing, Holt-winter smoothing.

MODULE III: Detailed study of the linear time series models: Autoregressive processes - Stationarity conditions, Autocorrelation function, Yule Walker estimation for AR processes and Partial autocorrelation function, Moving average process - Invertibility conditions, Autocorrelation function and Partial autocorrelation function.

MODULE IV: Economic Statistics: The problem of Index Numbers, Calculation of the Indexes – Ratio of simple aggregates, Ratio of weighted aggregates, Choice of a base period, fixed base and chain base methods- Advantages and disadvantages, Errors in Index Number Formulae-Formula

error, Sampling error and Homogeneity error. Different Tests of a good Index Number-Unit test, Time Reversal test, Factor reversal test and circular test. Cost of living Index Number.

MODULE V: Vital Statistics: Measures of Mortality-Crude death rate, Specific death rate. Adjusted Measures of Mortality-Direct method of adjusting, Indirect method of adjusting. Life table-Calculation of life-tables, Force of Mortality, Abridged life table, Uses of life table. Measurement of Fertility- Crude birth rate, General fertility rate, Age specific fertility rate, Total fertility rate. Measurement of population growth- Crude rate of natural increase, Gross reproduction rate, Net reproduction rate.

MODULE VI:: Official Statistics: Indian Statistical System, International Statistical System, Functions and Activities of Ministries of Statistics and Programme Implementation and Central Statistical Organization, Annual survey of industries, Agricultural census in India, National Sample Survey Organization, Population Census, Introduction to system of National Accounts.

REFERENCES

- Alan Pankratz (1994): Forecasting with Univariate Box-Jenkin Models, John Wiley.
- Anderson, T.W. (1971): Statistical Analysis of Time series, wiley.
- Basic Statistics Relating to the Indian Economy (CSO) 1990.
- Box, G.E.P., Jenkins G.M. and Reinsel, G.C. (2007) Time Series Analysis, Forecasting and Control, Pearson Education.
- Chatfield, C. (1980): The Analysis of Time Series-An Introduction, Second edition, Chapman and hall.
- Cox, P.R. (1957): Demography, Cambridge University Press.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1986): Fundamentals of Statistics, Vol. II, World Press, Calcutta.
- Guide to Official Statistics (CSO) 1995.
- Medhi, J. (1992): Statistical methods: An Introductory Text, New Age, Delhi.
- Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency Pvt. Ltd., Calcutta.
- Ramakumar, R. (1986): Technical Demography, Wiley Eastern.
- Statistical System in India (CSO) 1995.

SEMESTER **:** II
COURSE CODE **:** STA-CC-523
COURSE TITLE **:** MULTIVARIATE ANALYSIS
CREDITS **:** 4

COURSE OUTCOME

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

CO1: Describe multivariate normal distribution and its properties
CO2: Find the marginal and conditional distribution of multivariate normal distribution
CO3: Find the distribution of quadratic forms of multivariate normal vectors
CO4: Describe Wishart distribution and its properties
CO5: Obtain the estimators for parameters of multivariate normal distribution
CO6: Describe multiple and partial correlation coefficients
CO7: Define sample multiple and sample partial correlation coefficients for multivariate normal vector
CO8: Test the hypothesis regarding parameters of multivariate normal distribution
CO9: Use Hotelling's T^2 and Mahalanobis D^2 statistics for testing hypothesis
CO10: Perform Multivariate data analysis

MODULE OUTCOME

MODULE	**Module outcomes** On completion of each module, students should be able to:	**Taxonomy Level**
MODULE 1	MO1: Define the multivariate normal density function. MO2: Obtain the characteristic function of multivariate normal density MO3: Find the distribution of linear combination of multivariate normal random vector using characteristic function MO4: Find regression of multivariate normal distribution using conditional distribution	Remember Understand Apply Apply
MODULE 1I	MO1: Characterize quadratic forms of multivariate distribution. MO2: Obtain the distribution of sums and quotients of quadratic forms. MO3: Apply Cochran's theorem to find distribution of quadratic forms of multivariate normal random vector	Apply Apply Apply
MODULE III	MO1: Obtain the MLEs of mean and variance of multivariate normal distribution MO2 : Find the characteristic function of Wishart distribution MO3 : Show that Wishart distribution possess additive property MO4 : Find the distribution of sample dispersion matrix	Evaluate Apply Understand Remember
MODULE IV	MO1: Find the distribution of sample multiple correlation for multivariate normal distribution MO2: Find the distribution of sample partial correlation coefficients for multivariate normal distribution MO3: Obtain the distribution of test statistic for the test the significance of correlation coefficient and partial correlation coefficient.	Remember Apply Apply
MODULE V	MO1: Test the mean vector of a multivariate normal	Apply

	distribution MO2: Test the equality of means of two or more multivariate normal distributions MO3: Use Hotelling's T^2 and Mahalanobis D^2 statistics in testing hypothesis regarding multivariate normal distributions. MO4: Find the relationship between Hotelling's T^2 and Mahalanobis D^2 statistics	Apply Apply Understand
MODULE VI	MO1: Perform principal component analysis and factor analysis MO2: Classify individuals/items in to one of k multivariate normal populations MO3: Identify canonical variables and quantify canonical correlation	Analysis Analysis Analysis

COURSE CONTENT

MODULE I: Multivariate normal distribution, properties, characteristic function, standard characteristics, marginal and conditional distributions, distribution of linear combinations of normal variates.

MODULE II: Distribution of quadratic forms in normal variables, distribution of sums and quotient of independent quadratic forms, Cochran's theorem**.**

MODULE III : Samples from multivariate normal distribution, M.L.E. of mean vector and dispersion matrix, distribution of sample mean vector, Wishart distribution: definition, analogy with chi-square distribution, characteristic function, additive property, generalized variance, partitioned Wishart matrix, Distribution of sample dispersion matrix.

MODULE IV : Sampling distribution of correlation matrix and simple correlation coefficient, multiple correlation coefficient, partial correlation coefficient, distribution of the sample multiple correlation and partial correlation under null case, tests of significance.

MODULE V : Tests of hypothesis about mean vector of a multivariate normal distribution, equality of means of two multivariate normal distributions, Hotelling's T^2, Mahalanobi's D^2.

MODULE VI : Classification problem- classifying to one of k multivariate normal populations, Bayes solution, Fisher's discriminant function, principal component analysis; canonical variables and canonical correlations, basics of factor analysis and cluster analysis.

REFERENCES

- Anderson, T.W. (2003) :An Introduction to Multivariate Statistical Analysis, John Wiley, New York.

- Graybill, F. A. (1961): An Introduction to Linear Statistical Model, Vol. 1, McGraw Hill, New York.
- Johnson, R and Wychern (1992): Applied Multivariate Statistical Analysis, Prentice hall, London.
- 4. Kendall, M. G. (1958) :A Course in Multivariate Analysis, Griffin, London.
- Khatri, C.G. and Srivastava (1979) : An Introduction to Multivariate Statistics, North – Holland, New York.
- Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley & Sons New York.
- Rao, C.R.(1973) : Linear Statistical Inference and its Applications, Wiley Eastern, New York.
- Rohatgi, V.K.(1976): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd, New York.

SEMESTER **:** II
COURSE CODE **:** STA-CC-524
COURSE TITLE **:** PROBABILITY THEORY
CREDITS **:** 4

COURSE OUTCOMES

On completion of the course, students should be able to:
CO1. Identify a probability measure and explain its properties
CO2. Solve problems based on various properties of a probability measure
CO3. Apply the concepts of Bayes theorem and solve related problems
CO4. Distinguish between a discrete and continuous type random variables and illustrate with examples
CO5. Verify the properties of important functions of random variables
CO6. Calculate the expectation and moments of random variables and random vectors
CO7. Identify the applications of various moment inequalities
CO8. Explain the concept of convergence and check for the of convergence of a given sequences of random variables.
CO9. Find the expressions for the characteristic function of a random variable and verify its properties
C10. Apply the various laws of large numbers to sequences of random variables.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy Level**

Module 1.	M01. Explain and exemplify the concepts of probability space M02. Examine the various properties of a probability measure. M03. State and explain various results associated with probability measure M04. Explain the concepts of independence of events M05. Construct examples of independent events M06. Construct counter examples for proving/illustrating certain results associated with probability measure M07. Evaluate the conditional probability and verify its properties M08. Articulate the Bayes theorem and apply it to calculate apriori probabilities	Understand Analysis Understand Remember Create Create Evaluate Apply
Module: 2	M01. Distinguish between various types of random variables and articulate their properties M02. Describe the various functions of random variables and find the functions for various random variables M03. Explain and exemplify the concepts of decomposition of distribution function of a random variable M04. Articulate/exemplify various types of distributions and their important properties	Apply Apply Understand Understand
Module 3	M01. Calculate the mathematical expectation, moments and generating functions of random variables M02. Explain the concepts of random vectors and distribution function of random vectors, and their important properties M03. Articulate the various moment inequalities M04. Apply the various moment inequalities to various distributions	Evaluate Understand Understand Apply
Module 4	M01. Articulate and appraise stochastic convergence of sequence of random variables M02. Apply the concepts of convergence to sequences of random variables M03. Construct counter examples for not satisfying certain convergence implications	Understand Evaluate Create
Module 5	M01. Derive expressions for the characteristic function for various distributions M02. Find moments using characteristic function M03. Derive expressions for the probability density function corresponding to a given characteristic function M04. Articulate the various theorems associated with the characteristic function and identify their applications M05. Explain and exemplify the concepts of infinitely divisible distributions	Evaluate Evaluate Evaluate Apply Understand
Module 6.	M01. State and prove the various laws of large numbers M02. Apply the laws to sequences of random variables M03. Articulate the concepts of stable distributions M04. Explain the concepts of Stable distributions and distribution of class L	Understand Apply Understand Understand

COURSE CONTENT

MODULE I: Probability space, limit of sequence of events, monotone and continuity properties of probability measure, addition theorem, independence of finite number of events, sequence of events, tail events and tail fields, Borel Cantelli lemma, Borel zero one law. Conditional Probability and Bayes Theorem.

MODULE II: Random variable, its probability distribution and distribution function, properties of distribution function, decomposition of distribution function, discrete and continuous type random variables, discrete & continuous and other types of distributions,

MODULE III: Mathematical expectation, moments of random variables, random vectors, independence of random variables and sequence of random variables, Markov, Chebyshev's and Lyapounov inequalities.

MODULE IV: Stochastic convergence of sequence of random variables:- convergence in distribution, convergence in probability, almost sure convergence and convergence in the rth mean, their interrelationships, examples and counter examples, Helly's and Helly-Bray theorems (statements only).

MODULE V: Characteristic function and their elementary properties, uniform continuity and nonnegative definiteness of characteristic function, characteristic function and moments, inversion theorem (proof not required), uniqueness theorem, Fourier inversion theorem, continuity theorem, Bochner-Khintchine theorem of characteristic functions(proof not required), infinite divisibility of distributions(definition and elementary properties).

MODULE VI: Stochastic convergence of series of random variables:-Law of large numbers, weak law of large numbers: Bernoulli, Chebyshev & Khintchine, Kolmogorov inequality, strong law of large numbers: Kolmogorov- iid & non-iid cases (proof not required), central limit theorem: Classical, Demoiver-Laplace, Liapounov and Lindberg-Feller (without proof), Stable distributions: distribution of class L, stable distributions & domain of attraction(definition and examples only).

REFERENCES

- Bhat, B.R. (1985): Modern Probability Theory: An Introductory Text Book, 2nd edition, Wiley Eastern.
- Gnedenoko, B.V. (1969): The Theory of Probability, Mir Publishers, Moscow.
- Laha, R.G. and Rohatgi, V.K. (1979) : Probability Theory, John Wiley, New York
- Loeve, M. (1968): Probability Theory, D.Van Nostrand Co.Inc., Princeton, New Jersey.

SEMESTER : II
COURSE CODE : STA-CC-525
COURSE TITLE : PRACTICAL-I
CREDITS : 2

After completion of this course the students will be able to

COURSE OUTCOMES

C01. Evaluate the trend and seasonal fluctuations of a real life time series data using R programming language
C02. Formulate different Index numbers for economic data
C03. Demonstrate different sampling techniques using real life data set
CO4. Outline relative efficiency of sampling procedures
C05. Illustrate different statistical tests using the software SPSS
C06. Interpret different multivariate techniques using SPSS

MODULE OUTCOMES

Sl.No.	Outcomes On Completion of each module, Students should be able to:	Taxonomy level
Module 1.	M01. Evaluate the Trend component of a time series using different methods like Method of Semi-Averages, Method of Curve fitting , Moving average Method Using the R programming M02. Generate the Seasonal component of a time series using different method like method of simple averages, Ratio to trend method, Ratio to moving average method, Link relative method Using the R programming	Evaluate Create
Module.2	M01. Generate different Index numbers using different methods like Simple Aggregate method, Weighted aggregate method: Laspeyres, Paasches', Bowley, Marshall-Edgeworth, Fisher index numbers, Computation of cost of living index numbers Using the R programming M02. Calculate different measures of mortality such as CDR, SDR, completing of missing life table, computation of measures of Fertility such as CBR, GFR, SFR, TFR, GRR, NRR Using the R programming	Create Apply
Module.3	M01. Design different sampling techniques such as Simple random sample with and without replacement, PPS sample, with and without replacement, Midzuno-Sen sample ,linear systematic sample, circular systematic sample, multiple start systematic sample Using the R	Create

	programming. M02.Determine different estimates such as Estimate of population mean (total) and estimate of standard error of the estimate of mean(total based upon a simple random sample with or without replacement, linear systematic sample, circular systematic sample, multiple start systematic sample ,stratified random sample, cluster sample, two stage sample). Estimated gain in efficiency due to stratification Using the R programming.	Apply
Module 4	M01. Outline relative efficiency of cluster as a unit of sampling compared to an element as unit of sampling, Relative efficiency of two stage sampling and systematic sampling Using the R programming. M02. Evaluate Ratio and regression estimator of population mean based on a simple random sample without replacement Using the R programming.	Remember Evaluate
Module 5	M01. Perform tests of hypothesis such as Compare means- one sample t- test, two sample test, independent sample t test, chi-square test using the software SPSS. M02. Illustrate the concepts of correlation and Regression-simple and multiple using the software SPSS.	Apply Apply
Module 6	M01. Perform tests of hypothesis using multivariate data such as Equality of means of two multivariate normal vectors M02.Analyze the multivariate data using the multivariate techniques such as Canonical correlation, Principal component analysis, Factor analysis, Cluster analysis.	Apply Analyze

COURSE CONTENT

MODULE 1: (Using R programming) Measurement of the Trend: Method of Semi-Averages, Method of Curve fitting , Moving average Method, Measurement of Seasonal Fluctuations: Method of simple averages, Ratio to trend method, Ratio to moving average method, Link relative method.

MODULE 1I: (Using R programming) Calculation of the Index numbers: Simple Aggregate method, Weighted aggregate method: Laspeyres, Paasches', Bowley, Marshall-Edgeworth, Fisher index numbers, Computation of cost of living index numbers Computation of different measures of mortality: CDR, SDR, completing of missing life table, computation of measures of Fertility: CBR, GFR, SFR, TFR, GRR, NRR.

MODULE III: (Using R programming) Selection of a random sample :Simple random sample with and without replacement, PPS sample, with and without replacement, Midzuno-Sen sample ,linear systematic sample, circular systematic sample, multiple start systematic sample.

Estimation; Estimate of population mean (total) and estimate of standard error of the estimate of mean(total based upon a simple random sample with or without replacement, linear systematic sample, circular systematic sample, multiple start systematic sample ,stratified random sample, cluster sample, two stage sample. Estimated gain in efficiency due to stratification,

MODULE 1V: (Using R programming) Relative efficiency of cluster as a unit of sampling compared to an element as unit of sampling, Relative efficiency of two stage sampling and systematic sampling. Ratio and regression estimator of population mean based on a simple random sample without replacement.

MODULE V: (Using SPSS) Descriptive Statistics ; Compare means- one sample t- test, two sample test, independent sample t test ; chi-square test ; Correlation; Regression-simple and multiple.

MODULE VI: (Using SPSS) Equality of means of two multivariate normal vectors; Canonical correlation, Principal component analysis, Factor analysis, Cluster analysis.

SEMESTER **:** III
COURSE CODE **:** STA- CC-531
COURSE TITLE **:** STOCHASTIC PROCESSES
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Describe and exemplify concepts of Stochastic processes, time space and state space, classification of stochastic processes based on the nature of time space and state space, Classical stochastic processes like processes with stationary independent increments, Markov process, renewal process, martingales, Wiener process, Gaussian process
CO2. Explain Markov chains: Definition, transition probability matrix, n-step transition Probability and Chapman-Kolmogorov equation
CO3. Calculate n-step transition probabilities
CO4. Classify states of a finite Markov chain
CO5. Describe periodicity and ergodicity of chains.
CO6. Describe limiting behaviour of n-step transition probabilities,
CO9.Obtain the stationary distribution of a Markov chain
CO10. Describe random walks & gambler's ruin problem.
CO11. Explain and exemplify continuous time Markov chain, Poisson process, pure birth process, birth and death processes, compound Poisson process, Markov Process with discrete states.
CO12. Distinguish between strict and weak (covariance or wide sense) stationarity,

CO 13. Explain and exemplify renewal processes, renewal equation.
CO14. Describe and apply renewal theorem.
CO15. Describe Branching processes, offspring distribution, extinction probabilities.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy Level**
Module 1.	M01. Articulate and exemplify the concepts of Stochastic processes, time space and state space. M02. Construction of examples of Stochastic processes M03. Explain the concepts of particular types of stochastic processes like process with stationary independent increments, Markov process, martingales, Wiener process, Gaussian process etc.	Understand Understand Create Apply
Module: 2	M01. Articulate concepts of Markov chains, transition probability matrix, n-step transition probabilities M02. Calculate n-step transition probabilities M03. Describe and exemplify classification of states in a Markov Chain M04. Calculate the periodicity of a Markov Chain M05. Explain the concepts of recurrence, ergodic chains	Understand Evaluation Understand Evaluation Understand
Module 3	M01. Explain and exemplify concepts of limiting behaviour of n-step transition probabilities. M02. Describe stationary distributions and solve problems M03. Describe various types of random walks M04. Explain a gambler's ruin problem M05. Derivation of the probability of ruin of a gambler's ruin problem	Understand Apply Understand Understand Evaluation
Module 4	M01. Describe and exemplify: Continuous time Markov chains, Poisson process, pure birth process, birth and death processes. MO2. Derive of steady state probabilities/differential difference equations in case of Poisson process, pure birth process, birth and death processes. M03. Describe and exemplify: Compound Poisson process, M04 Derive properties of Poisson process and Compound Poisson process M05. Explain the concept of Markov Process with discrete states. M06. Illustrate these processes with examples	Understand Evaluation Understand Evaluation Understand Apply
Module 5	M01. Distinguish between strict and weak (covariance or wide sense) stationarity M02. Describe and exemplify: renewal processes, renewal equation.	Analyse Understand

	M03. Explain the statement and applications of renewal theorem M04. Solve problems based on the applications of renewal theorem	Apply Apply
Module 6	M01. Describe and exemplify Galton-Watson branching processes M02. Explain concepts of offspring distribution and its implications M03. Interpret the concept of extinction probabilities M04. Compute the probability extinction in case of a particular offspring distribution.	Understand Apply Apply Apply

COURSE CONTENT

MODULE I: Introduction to Stochastic processes, time and state space, classification of stochastic processes, processes with stationary independent increments, Markov process, renewal process, martingales, Wiener process, Gaussian process (definitions and examples).

MODULE II: Markov chains: Definition, transition probability matrix, n-step transition probability, Chapman-Kolmogorov equation, calculation of n-step transition probability and its limit, classification of states, periodicity, recurrence, ergodic chains,

MODULE III: limiting behaviour of n-step transition probabilities, stationary distributions, random walk & gambler's ruin problem.

MODULE IV: Continuous time Markov chains, Poisson process, pure birth process, birth and death processes, compound Poisson process, Markov Process with discrete states.

MODULE V: Stationary processes, strict and weak (covariance or wide sense) stationarity, renewal processes, renewal equation, statement and applications of renewal theorem.

MODULE VI: Branching process: Galton-Watson branching processes, offspring distribution, extinction probabilities.

REFERENCES

- Bartlett, M.S. (1955): An Introduction to Stochastic Processes (with special reference to application and methods), Cambridge.
- Bhat, U.N. and Miller, G.K. (2002): Elements of Applied Stochastic Processes. 3rd Edn., John Wiley, New York.
- Feller, W. (1968): Introduction to Probability Theory and its Applications, Vols. I & II, John Wiley, New York.
- Karlin, S. (1972): A First Course in Stochastic Processes, Academic Press, New York.
- Parzen, E. (1962): Stochastic Processes, Holden-Day Inc, San Francisco.

- Srinivasan, S.K. and Mehata, K.M. (1976): Stochastic Processes, Tata McGraw-Hill Publishing Company Limited, New Delhi.

SEMESTER : III
COURSE CODE : STA-CC-532
COURSE TITLE : ESTIMATION
CREDITS : 4

COURSE OUTCOMES

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

C01:List the important properties of estimators of an unknown parameter of a distribution
C02:Derive the UMVUE of a parameter or function of a parameter
C03:Apply the concept of Rao-Blackwell and Lehmann-Scheffe theorems
C04:Able to select the best estimators using different properties
C05: Differentiate between classical and Bayesian inference
C06: Determine the estimators of unknown parameters using methods like MLE, Method of moments etc.
C07: Differentiate between location and scale family of distributions
C08:Outline Bayes estimation of parameters of standard distributions

MODULE OUTCOMES

Sl.No.	Outcomes On Completion of each module, Students should be able to:	Taxonomy level
Module 1.	M01. Derive the important properties of estimators M02.Determine the sufficient statistic using NP lemma M03.Explain minimal sufficiency M04.Define Basu's Theorem M05.Use likelihood equivalence to obtain minimal sufficient statistic	Create Evaluate Understand Remember Apply
Module.2	M01. Develop a characterization theorem for finding UMVUE M02. Apply Rao-Blackwell and Lehmann-Scheffe theorems to find UMVUE M03. Determine UMVUE estimator of any parametric function	Create Apply Apply
Module.3	M01. Derive Fisher information measure M02. Calculate Cramer-Rao inequality, Chapman -Robbin's bound, Bhattacharya bounds.	Create Apply

	M03. Identify Efficient estimators M04. Evaluate Consistent estimators	Remember Evaluate
Module 4	M01. Describe different methods of estimation such as method of moments, MLE, Minimum chi-square, Least square estimation etc. M02. Derive properties of the estimators	Understand Create
Module 5	M01. Formulate location and scale family of distributions M02. Evaluate Location and scale invariant estimators M03. Calculate Pitman estimators of location and scale parameters M04. Discuss BLUE for location and scale distributions.	Create Evaluate Apply Understand
Module 6	M01. Design basic elements of Bayesian Inference M02. Define Bayes Theorem M03.Calulate Bayes estimators of parameters of standard distributions. M04.Differentiate between classical and Bayesian Inference	Create Remember Apply Analyze

COURSE CONTENT

MODULE I: Point estimation, Sufficiency and minimal sufficiency, Neyman-Pearson factorization theorem, Exponential family of distributions, Pitman family, Likelihood equivalence, Unbiased estimation; Completeness, Basu's Theorem.

MODULE II: UMVUE estimators and their characterizations, Methods of finding UMVUE, Rao-Blackwell and Lehmann-Scheffe theorems, UMVUE estimation of parametric function from standard distributions.

MODULE III: Fisher information measure and its properties, Lower bound to the variance of an unbiased estimates, Cramer-Rao inequality. Chapman -Robbin's bound, Bhattacharya bounds, Efficiency, Consistency.

MODULE IV: Methods of estimation: Method of moments, Maximum likelihood estimators and their properties, Minimum chi-square and its modification, Least square estimation.

MODULE V: Location and scale family of distributions, Location and scale invariant estimators, Pitman estimators of location and scale parameters. BLUE for location and scale distributions.

MODULE VI: Basic elements of Bayesian Inference, Loss function, Bayes risk, Prior distribution, Bayes Theorem, Posterior distributions, Bayes estimation of parameters of standard distributions.

REFERENCES

- Hogg, R. V. and Craig, A. T. (1989): Introduction to Mathematical Statistics, Macmillan Publishing Company.
- Kale, B. K. (1999): A First Course on Parametric Inference, Narosa Publishing House.
- Kendall, M.G. and Stuart, A. (1967): The Advanced Theory of Statistics, Vol. II, 2nd Edition, Charles Griffin & Company Ltd., London.
- Lehmann, E. L. (1983): Theory of Point Estimation, John Wiley, New York.
- Mood, A. M., Graybill, F. A. and Boes, D. C.(1972): Introduction to the Theory of Statistics, 3rd Edition, Mc-Graw Hill International, New York.
- Mood, A. M., Graybill, F. A. and Boes, D. C.(1972): Introduction to the Theory of Statistics, 3rd Edition, Mc-Graw Hill International, New York.
- Rajagopalan M. and Dhanavanthan, P. (2012) Statistical Inference, PHI Learning Private Limited, New Delhi.
- Rohatgi, V. K. (1990): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Limited.
- Wasan, M. T. (1970): Parametric Estimation, Mc-Graw Hill, New York.

SEMESTER **:** III
COURSE CODE **:** STA-CC-533
COURSE TITLE **:** TESTING OF HYPOTHESES
CREDITS **:** 4

COURSE OUTCOME

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

CO 1: Formulate hypothesis for a given problem
CO2: Find critical region and power of the test
CO3: Find most powerful test for testing simple hypothesis against simple alternative
CO4: State and prove Neyman-Pearson lemma
CO5: Find UMP test for testing composite hypothesis
CO6: Obtain LMP and LMPU test
CO7: Derive likelihood ratio test for testing the hypothesis for normal populations
CO8: Obtain sequential probability ratio test for testing the hypothesis.
CO9: Construct confidence interval for parameters
CO10: Construct UMA and UMAU confidence sets

MODULE OUTCOME

MODULE	Module outcomes On completion of each module, students should be able to:	Taxonomy Level
MODULE 1	MO1: Identify simple and composite hypothesis MO2: Find critical region, size and power of the test MO3: Distinguish between random and non-randomized test	Understand Evaluate Apply
MODULE 1I	MO1: Apply Neymann-Pearson lemma to find most powerful test MO2: Check the unbiasedness of a test MO3: Find UMP and UMPU test	Apply Apply Apply
MODULE III	MO1: Obtain Locally Most Powerful test MO2: Obtain Locally Most Powerful Unbiased test MO3: Define general linear hypothesis	Apply Apply Remember
MODULE IV	MO1: Apply likelihood ratio test principle for testing the mean for a normal population. MO2: Apply likelihood ratio test principle for testing the equality of means for two normal population MO3: Test the variance of normal population. MO4: Test the equality of means of two normal populations	Apply Apply Apply Apply
MODULE V	MO1: Derive SPRT for test the parameters of normal distribution, binomial and Poisson distributions MO2: Find OC function and Average sample Number of a SPRT	Apply Remember
MODULE VI	MO1: Construct shortest level confidence interval for parmeters MO2: Obtain confidence interval using pivot MO3: Use UMP and UMPU test to construct UMA and UMAU confidence sets	Evaluate Apply Apply

COURSE CONTENT

MODULE I: Basics of Testing of hypothesis, simple hypotheses and composite hypotheses, critical regions and test functions, randomized and nonrandomized tests,

MODULE II: Neyman-Pearson lemma and its applications, most powerful tests, UMP tests, Unbiasedness, UMPU

MODULE III: LMP, LMPU, tests of hypotheses concerning a real parameter, similar regions, Introduction to general linear hypotheses.

MODULE IV: Likelihood ratio tests, asymptotic properties, tests concerning normal distribution (one sample and two samples) and binomial distribution.

MODULE V: Sequential procedures, SPRT-Wald's identity- OC and ASN functions, applications to Binomial, Poisson and Normal distributions

MODULE VI: Confidence sets, shortest confidence intervals, construction of confidence interval using pivots, most accurate-UMA, UMAU confidence sets-relation to tests of hypotheses, interval estimation.

REFERENCES

- Ferguson, T. S. (1967): Mathematical Statistics, Academic Press, New York.
- Kendall, M.C, and Stuart. A, (1967): The Advanced Theory of Statistics, Vol 2, IV Edn., Mc Millan, New York.
- Lehmann, E. L. (1986): Testing of Statistical Hypothesis, John Wiley & Sons.
- Wald, A.(1977): Sequential Analysis, Dover Publications Inc., New York.
- Wetherill, G. B. (1966): Sequential Methods in Statistics, Methuen & Co. Ltd. New Delhi.

SEMESTER : III
COURSE CODE : STA-DE-534(i)
COURSE TITLE : STATISTICAL QUALITY CONTROL AND RELIABILITY MODELING
CREDITS : 4

COURSE OUTCOMES

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

CO1. Understand the concept of quality control statistical process control.

CO2. Measure the performance of a process.

CO3. Identify assignable causes.

CO4. Define reliability including the different types and how they assessed.

CO5. Ensure the validity and precision of statistical analysis.

CO6. Explains reliability in discrete set up.

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy level
Module 1	M01. Explain statistical process control M02. Describe various control charts	Understand Evaluate
Module 2	M01. Describe different sampling inspection techniques M02. Explains six-sigma concepts M03. Distinguish chain sampling and continuous sampling	Evaluate Understand Remember
Module 3	M01. Explain basic concepts of reliability M02. Describe reliability of a coherent system M03. Describe several measures of reliability M04. Calculate measures of reliability based on several distributions	Understand Remember Remember Analysis
Module 4	M01. Explain reliability in discrete set up M02. Derive expression of the relation connecting various measures of reliability	Understand Evaluate
Module 5	M01. Explain inference in reliability models M02. Describe estimation of parameters based on censored sampling MO3. Solve problems related to estimation of parameters based on censored sampling	Understand Apply Apply

COURSE CONTENT

MODULE I: Statistical process control, Theory of control charts – Shewart control charts for variables- $\bar{X}$, R,S charts, Attribute control charts - np, p, c and u charts – OC, ARL & process capability of control charts, CUSUM charts, Acceptance sampling for attributes and variables.
MODULE II: Sampling inspection techniques: Single, double and multistage sampling plans and their properties, Chain sampling, Continuous sampling, Taguchi method, Total quality management, ISO standardization, ISO 9001, six sigma concepts.

MODULE III: Basic reliability concepts: Reliability concepts and measures, Components and systems, coherent systems, reliability of coherent systems, cuts and paths, series and parallel system, k-out-of-n systems, Bounds on System Reliability. Failure rate, mean residual life, Mean time to failure in the univariate cases, Exponential, Weibull, Pareto, Inverse Gaussian and

Gamma as life distribution models, Characterization of life distribution based on failure rate and mean residual life function.

MODULE IV: Reliability concepts in discrete set up, Notion of ageing based on failure rate and mean residual life, NBU, NBUE, HNBUE classes and their duals, Interrelationships.

MODULE V: Inference in reliability models: Estimation of parameters based on complete and censored samples in exponential, Weibull and Gamma models. Non-parametric estimation of failure rate and reliability function.

REFERENCES

- Barlow, R.E. and Proschan, F. (1985): Statistical Theory of Reliability and Life Testing, Holt, Rinehart and Winston.
- Cox, D.R. and Oakes, D. (1984): Analysis of Survival Data, Chappman Hall.
- Duncan, A. J. (1959): Quality Control and Industrial Statistics (5th edition), Irwin, Homewood I.
- Galambos, J. and Kotz, S. (1978) Characterization of Probability Distributions.
- Klefjo, B. (1982) The HNBUE and HNWUE Classes of Life distributions, Naval Research Logistic Quarterly, 29, 331-344.
- Lawless, J. F. (2003): Statistical Models and Methods for Lifetime Data, John Wiley.
- Montgomery, D.C. (2005): Introduction to Statistical Quality Control, 5th edition, John Wiley.
- Nelson, W. (1982): Applied life data analysis, Wiley.
- 9. Sinha, S. K. (1986) Reliability and Life Testing, Wiley.

SEMESTER **:** III
COURSE CODE **:** STA-DE-534(ii)
COURSE TITLE **:** ADVANCED PROBABILITY THEORY
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Identify the concept of probability through Kolmogorov's Axiom.

CO2. Explain the concept of probability density function and cumulative distribution function.

CO3. Explain the concept random vectors and random variables.

CO4. Apply central limit theorem and articulate the problems related to central limit theorem.

CO5. Apply central results in probability theory on typical problems within the fields.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy level**
Module 1	M01. Explain and exemplify the concept of random vectors and infinite dimensional random variables. M02. State and explain consistency theorem. M03. State and prove Kolmogorov 0-1 law.	Understand Remember Remember
Module 2	M01. Explain convolution semigroup. M02. Describe the representation of the infinitesimal generators.	Understand Evaluate
Module 3	M01. Describe divisible distribution and elementary properties. M02. Explain canonical representations. M03. Describe convolution semigroups and infinitely divisible distribution.	Apply Understand Analysis
Module 4	M01. State and explain general central limit theorem. M02. Apply central limit theorem and solve problems related to it.	Remember Apply
Module 5	M01. Explains distribution of class L M02. Distinguish extreme value distributions and stable distributions. M02. Establish domain of attraction.	Understand Evaluate Apply

COURSE CONTENT

MODULE I: Random Vectors, Infinite dimensional random variables, consistency theorem, Tail events, Tail fields, tail –functions, Kolmogorov 0-1 law, Exchangeability, Hawitt-Savage 0-1 law, Centering and truncation.

MODULE II: Convolution semi-group, probability operators, representation of the infinitesimal generators.

MODULE III: Infinitely divisible distribution, elementary properties, Canonical representations,
Convolution semi groups and infinitely divisible distributions.

MODULE IV: The general central limit problem, normal, degenerate and Poisson convergence.

MODULE V: Distributions of class L, Stable distributions, Domain of Attraction. Extreme value Distributions.

REFERENCES

- Laha, R. G. and Rohatgi, V. K. (1979): Probability Theory, John Wiley & Sons, New York.
- Feller, W. (1968) : An Introduction to Probability Theory and Its Applications, Vol 1, John Wiley, New York.
- Feller, W. (1971): An Introduction to Probability Theory and Its Applications, Vol. 2, John Wiley, New York.
- Fisz, M. (1963): Probability Theory and Mathematical Statistics, John Wiley, New York.

SEMESTER **:** III
COURSE CODE **:** STA-DE-534(iii)
COURSE TITLE **:** DATA MINING
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Able to learn the concept of data base technology which has led to the need for data mining and its applications

CO2. Examine the types of data to be mined and present a general classification of task to integrate data mining system.

CO3. Evaluate and select appropriate data mining algorithms and apply, interpret and report the output appropriately.

CO4. Apply statistical methods for any given raw data.

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy level
Module 1	M01. Explain classification methods for data M02. Establish decision trees	Understand Apply
Module 2	M01. Distinguish clustering from statistical and data mining M02. Explain vector quantization	Understand Analysis
Module 3	M01. Explain dimension reduction M02. Analyze unsupervised learning from univariate and multivariate data	Remember Analysis
Module 4	M01. Explain supervised learning from moderate to high dimensional input spaces M02. Analyze regression trees	Understand Evaluate
Module 5	M01. Explain simple relation data bases M02. Analyze online analytical data processing M03. Establish the applications to electronic commerce	Understand Evaluate Apply

COURSE CONTENT

MODULE I: Review of classification methods from multivariate analysis; classification and decision trees.

MODULE II: Clustering methods from both statistical and data mining viewpoints; vector quantization.

MODULE III: Unsupervised learning from univariate and multivariate data; dimension reduction and feature selection.

MODULE IV: Supervised learning from moderate to high dimensional input spaces; artificial neural networks and extensions of regression models, regression trees.

MODULE V: Introduction to databases, including simple relational databases; data warehouses and introduction to online analytical data processing. Association rules and prediction; data attributes, applications to electronic commerce.

REFERENCES

- Berson, A. and Smith, S.J. (1997): Data Warehousing, Data Mining, and OLAP. McGraw-Hill.
- Breiman, L. Friedman, J.H. Olshen, R.A. and Stone, C.J. (1984): Classification and Regression Trees. Wadsworth and Brooks/Cole.
- Han, J. and Kamber, M. (2000): Data Mining; Concepts and Techniques. Morgan Gaufmann.
- Mitchell, T.M. (1997): Machine Learning. McGraw-Hill.
- Ripley, B.D. (1996): Pattern Recognition and Neural Networks. Cambridge University Press.

SEMESTER **:** IV
COURSE CODE **:** STA-CC-541
COURSE TITLE **:** NONPARAMETRIC METHODS
CREDITS **:** 4

After completion of this course the students will be able to

COURSE OUTCOMES

C01.Find joint, marginal and conditional probability distributions of order statistics in the continuous and discrete cases.
C02. Find the distribution of sample range and other systematic statistics in case of sampling from an arbitrary continuous population and, in particular, from some specific continuous distributions such as uniform and exponential.
C03. Understand the Markov Chain property of order statistics
C0 4. Derive the recurrence relations and identities for moments of order statistics drawn from an arbitrary population (discrete or continuous), as well as from some specific distributions.
C05 learn about the large sample approximations to the mean and variance of order statistics as well as the asymptotic distributions of order statistics.
C06.Find the distributions of order statistics for independently and not identically distributed variates and also for dependent variates.
C07. Solve hypothesis testing problems where the conditions for the traditional parametric inferential tools to be applied are not fulfilled.

MODULE OUTCOMES

Sl.No.	Outcomes On Completion of each module, Students should be able to:	Taxonomy level
Module 1.	M01.Explain the distribution and density functions of single order statistics	Understanding
	M02.Solves the Joint distribution and density functions of two order statistics.	Applying
	M03. Evaluates the conditional distribution theory of order statistics.	Evaluate
	M04. Composes the distributions of some well-known statistics - sample median and sample range	Create
	M05.Oultines the Markov property of order statistics.	Remembering
Module.2	M01.Demonstartes single moments and product moments of order statistics.	Applying
	M02. Evaluates the recurrence relations on the moments and product moments of order statistics	Evaluating
	M03. Designs exponential order statistics and uniform order statistics.	Creating
Module.3	M01. Computes estimates of location and scale parameters of a distribution by order statistic	Applying
	M02. Constructs the estimates of location and scale parameters of a symmetric distribution by order statistic.	Applying
	M03.Produces the estimates of the scale parameters of a distribution belonging to the scale family of distribution.	Applying
	M04. Creates the Gupta's simplified linear estimates of location and (or) scale parameters of a distribution by order statistics.	Creating
Module 4	M01. Define U statistic, Variance and asymptotic variance of U statistic.	Remembering
	M02.Constructs one sample U-statistic theorem with proof,	Applying
	M03. Explain the Definition and examples of two sample U-statistics, variance of two sample U-statistic.	Understanding
	M04. Outlines the Two sample U-statistic theorem	Remembering
	M05. Generates the Mann-Whitney U-statistic and its variance.	Creating
	M06. Writes the Test based on Mann-Whiteny Statistics.	Creating
Module 5	M01.Identifies the appropriate Nonparametric tests – Kolmogorov- Smirnov one sample and two sample tests,Sign test, Wilcoxon signed rank test, run test. Median test.	Analyzing
	M02. Explains the Kruskal-Wallis one-way analysis of variance by ranks, Friedman two way analysis of variance by ranks.	Evaluating
	M03. Illustrates Kendall's rank order correlation coefficient and Kendall's coefficient of concordance as measure of association.	Analyzing

Module 6	M01. States the Asymptotic Relative Efficiency (ARE) of tests. M02.Summarizes Pitman's ARE. M03.Concludes the Statement and applications of Noether's theorem. M04. Summarizes the Efficacy And ARE of one sample t test, sign test and Wilcoxon signed rank sum test.	Remembering Understanding Evaluating Creating

COURSE CONTENT

MODULE I: Order statistics, Distribution and density functions of order statistics, Joint distribution and density functions of two order statistics, Conditional distribution theory of order statistics, Distributions of some well-known statistics - sample median and sample range, Markov property of order statistics.

MODULE II: Single moments and product moments of order statistics, Recurrence relations on the moments and product moments of order statistics, Exponential order statistics, Uniform order statistics.

MODULE III: Application of order statistics in estimation- Estimation of location and scale parameters of a distribution by order statistic, Estimation of location and scale parameters of a symmetric distribution by order statistic. Estimation of the scale parameters of a distribution belonging to the scale family of distribution, Gupta's simplified linear estimation of location and (or) scale parameters of a distribution by order statistics.

MODULE IV: U-statistics: Definition and examples, Variance and asymptotic variance of U-statistic, Some properties of kernels, One sample U-statistic theorem with proof, Definition and examples of two sample U-statistics, variance of two sample U-statistic, Two sample U-statistic theorem (Statement Only), Mann-Whitney U-statistic and its variance. Test based on Mann-Whiteny Statistics.

MODULE V: Nonparametric tests –Kolmogorov- Smirnov one sample and two sample tests, Sign test, Wilcoxon signed rank test, run test. Median test. Kruskal-Wallis one-way analysis of variance by ranks, Friedman two way analysis of variance by ranks. Kendall's rank order correlation coefficient and Kendall's coefficient of concordance as measure of association.

MODULE VI: Asymptotic Relative Efficiency (ARE) of tests. Pitman's ARE. Statement and applications of Noether's theorem. Efficacy of one sample t test, sign test and Wilcoxon signed rank sum test. ARE of these tests.

REFERENCES

- David, H.A. and Nagaraja, H.N. (2003): Order Statistics, 3rd Edn. Wiley, New York.
- Prakasa Rao, B.L.S. (1983): Nonparametric Functional Estimation, Academic Press.
- Randles, R.H. and Wolfe, D.A. (1979): Introduction to the Theory of Nonparametric Statistics, Wiley, New York.
- Serfling, R.J. (1980): Approximation Theorems of Mathematical Statistics, Wiley, New York.
- Siegel, S. and Castellan Jr. N. J. (1988): Non-parametric Statistics for the Behavioral Sciences. McGraw Hill, New York.

SEMESTER **:** IV
COURSE CODE **:** STA-CC-542
COURSE TITLE **:** DESIGN AND ANALYSIS OF EXPERIMENTS
CREDITS **:** 4

COURSE OUTCOME

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

CO 1: Define linear parametric function and describe its properties
CO2: State Gauss-Markov theorem and its applications.
CO4: Perform Analysis of variances
CO3: Describe block designs and its properties
CO5: Design and analyse of block designs.
CO6: Design and analyse factorial experiments
CO7: Apply principle of total and partial confounding in factorial experiments
CO8: construct and analyse incomplete block design
CO10: Perform analysis of covariance.
CO11: Perform missing plot and mixed-up plots analysis

MODULE OUTCOME

MODULE	Module outcomes On completion of each module, students should be able to:	Taxonomy Level
MODULE 1	MO1: Identify estimability of a linear parametric function MO2: Apply Gauss-Markov theorem for finding BLUE of a parametric function. MO3: Formulate the model for one way and two way classification MO4: Perform one way and two analysis of varaince	Understand Apply Understand Analysis
MODULE 1I	MO1: Identify connected, balance and orthogonal designs	Understand

	MO2: Design and analysis of CRD, RBD, LSD and GLSD	Analysis
MODULE III	MO1: Design and analyse of 2^2, 3^n and p^n factorial experiments MO2: Apply principle of total and partial confounding in factorial experiments	Analysis Apply
MODULE IV	MO1 : Analyze BIBD with inter and intra block informations MO2: Analyse PBIBD with only two associates classes	Apply Apply
MODULE V	MO1:AnalysesSplit-plot and split-split plot designs MO2: Formulate the model for one way and two way analysis of covariance MO3: Perform one way and two way analysis of covariance	Apply Apply Apply
MODULE VI	MO1:Perform Missing plot analysis in RBD and LSD MO3: Perform mixed-up plot analysis in RBD and LSD MO2: Estimate missing yields in split plot and BIBD	Apply Analysis Evaluate

COURSE CONTENT

MODULE I: General linear models, estimability of linear parametric functions, Gauss-Markov theorem, tests of linear hypothesis, information matrix of block designs, criteria for connectedness, balance and orthogonality.

MODULE II: Randomization, replication and local control, one-way classification, two-way classification with equal and unequal number of observations per cell. Standard designs: CRD, RBD, LSD, GLSD. Efficiency of design and comparison.

MODULE III: Factorial designs: Statistical analysis of symmetrical factorial designs. Total and partial confounding in 2^n, 3^n and p^n experiments. Concepts of fractional replication.

MODULE IV: Incomplete block design, BIBD, analysis with recovery of inter block information and intra block information, PBIBD and analysis of PBIBD with only two associates classes.

MODULE V: Split-plot and split-split plot designs. Strip-plot design. Analysis of covariance technique in standard designs.

MODULE VI: Missing and mixed plot analysis in RBD, LSD. Estimation of missing yields in split plot design and BIBD.

REFERENCES

- Aloke Day (1986). Theoryof Block Designs .Wiley Eastern, New Delhi.
- Chakrabarti,M.C.(1962) : Mathematics of Design and Analysis of Experiments , Asia Publishing House, Bombay.

- Das, M. N. and Giri, N. (1979). Design and Analysis of Experiments. Wiley Eastern Limited, New Delhi.
- John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan.
- Joshi, D. D. (1987): Linear Estimation and Design of Experiments, Wiley Eastern, Wiley Eastern Limited, New Delhi.
- Montgomery,C.D.(1976): Design and Analysis of Experiments, John Wiley, New York.

SEMESTER **:** IV
COURSE CODE **:** STA-CC-543
COURSE TITLE **:** PRATICAL 2
CREDITS **:** 2

COURSE OUTCOMES

After completion of this course the students will be able to

C01.Formulate and evaluate different estimators for unknown parameters using the real life data set using R programming language
C02.Choose an appropriate UMP test for a real life data set using R programming language
C03.Classify the different control charts for industrial data set using R programming language
C04.Perform the appropriate nonparametric tests for a data set using R programming language
C05.Summarize different design of experiments for a statistical experimental data using R programming language
C06. Recognize different nonparametric tests such as ANOVA, RBD etc. For statistical experimental data using R programming language.

MODULE OUTCOMES

Sl.No.	Outcomes On Completion of each module, Students should be able to:	Taxonomy level
Module 1.	M01. Justify different estimation techniques – Maximum likelihood estimation, Uniformly minimum variance unbiased estimate, method of moments, method of minimum chi-square using the R software.	Evaluate
Module.2	M02. Develop different Testing of hypothesis procedures such as Most powerful test, Uniformly most powerful test, Uniformly most powerful unbiased test, Locally most powerful test, Likelihood ratio tests, Sequential probability ratio test using the R software.	Create

Module.3	M01. Illustrate different control charts such as Shewart control charts for variables- $\bar{X}$, R, S charts,Attribute control charts - np, p, c and u charts using the R software. M02. Formulate estimation of parameters based on complete and censored samples in exponential, Weibull and Gamma models using the R software. M03. Perform Nonparametric estimation of failure rate and reliability function using the R software.	Analyze Create Apply
Module 4	M01.Demonstrate different nonparametric tests such as Sign test, Wilcoxon signed rank test, run test, Median test. Kendall's rank order correlation coefficient and Kendall's coefficient of concordance as measure of association. Test based on Mann-Whitney Statistics. Friedman two way analysis of variance by ranks using the R software	Apply
Module 5	MO1. Formulate different experimental techniques such as LSD**,** ANCOVA, Factorial experiments. Missing and Mixed-up plot in RBD using the R software	Create
Module 6	M01. Demonstrate different tests procedures such as One way ANOVA, Two way ANOVA- multiple but equal, multiple but unequal, RBD, Kruskal-Wallis one-way analysis of variance by ranks, Kolmogorov- Smirnov one sample and two sample tests using SPSS software	Apply

COURSE CONTENT

MODULE I: (Using R) Estimation – Maximum likelihood estimation, Uniformly minimum variance unbiased estimate, method of moments, method of minimum chi-square.

MODULE II: (Using R) Testing of hypothesis – Most powerful test, Uniformly most powerful test, Uniformly most powerful unbiased test, Locally most powerful test, Likelihood ratio tests, Sequential probability ratio test.

MODULE III: (Using R) Control charts – Shewart control charts for variables- $\bar{X}$, R, S charts, Attribute control charts - np, p, c and u charts. Reliability- series and parallel system, k-out-of-n systems, Survival function, Hazard function, Mean residual life function in the univariate cases, Exponential, Weibull, Pareto and Gamma as life distribution models, Estimation of parameters based on complete and censored samples in exponential, Weibull and Gamma models, Non-parametric estimation of failure rate and reliability function.

MODULE IV: (Using R) Nonparametric tests – Sign test, Wilcoxon signed rank test, run test., Median test. Kendall's rank order correlation coefficient and Kendall's coefficient of

concordance as measure of association. Test based on Mann-Whitney Statistics. Friedman two way analysis of variance by ranks.

MODULE V: (Using R) LSD**,** ANCOVA, Factorial experiments. Missing and Mixed-up plot in RBD.

MODULE VI: (Using SPSS) One way ANOVA, Two way ANOVA- multiple but equal, multiple but unequal, RBD, Kruskal-Wallis one-way analysis of variance by ranks, Kolmogorov-Smirnov one sample and two sample tests.

SEMESTER **:** IV
COURSE CODE **:** STA-DE-544(i)
COURSE TITLE **:** OPERATIONS RESEARCH
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Describe Simplex method to solve the linear programming problem.
CO2. Explain the steps in solving a linear programming problem by two-phase method.
CO3. Explain the concept of duality in linear programming problem.
CO4. Give the outline of dual simplex method.
CO5. Describe the computational procedure of optimality test in a transportation table.
CO6. Explain the Hungarian method to solve the Assignment problem.
CO7. To understand basic structure of quadratic programming problem.
CO8. Give an account of different types of inventory models and inventory cost.
CO9. Derive an EOQ formula for different rate of demand in different cycles.
CO10. Formulate and solve the purchase inventory problem with one price break.
CO11. Derive the steady state solution of M/M/1 queue model.
CO12. Obtain expected number of units in the M/G/1 queueing system under steady state .
CO13. Derive an expression of the average annual cost of an item over a period of n years.
CO14. Describe Bellmen's principle of optimality.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy Level**

Module 1.	M01. Explain the concepts of linear programming problem. M02. Solve the linear programming problem by using Simplex method. M03. Computational steps of Big-m-Method M04. Write the dual of the given linear programming problem.	Understand Apply Remember Evaluate
Module: 2	M01. Find the initial basic feasible solution to the given Transportation problem. M02. To determine the optimum assignment problem. M03. State and prove Kuhn-Tucker necessary and sufficient conditions in a non-linear programming problem. M04. Describe briefly the Beal's method for solving quadratic programming problem.	Evaluate Evaluate Remember Remember
Module 3	M01. Explain with examples the probabilistic models in inventory. M02. Derive an expression for EOQ for Harri's or Wilson model. M03. Discuss the purchase inventory model with three price break.	Understand Understand Remember
Module 4	M01. State some of the important distributions of arrival interval and service time. M02. To evaluate expected value of queue length in various models. M03. Obtain the differential difference for M/M/1 queue model.	Remember Evaluate Understand
Module 5	M01. Describe the problem of replacement of items whose maintains cost increase with time. M02. Solve Dynamic programming problem by using Linear programming problem.	Understand Apply

COURSE CONTENT

MODULE I: Linear Programming: Convex sets and associated theorems, Graphical method, Computational aspects of simplex method, Duality problems of linear programming, Degeneracy and its solution, Two phase simplex method.

MODULE II: Transportation problems: Finding initial basic feasible solution, Optimality test, Degeneracy, Assignment problem, Hungarian method, Non-linear programming, Kuhn-Tucker theory for convex programming problem, Quadratic programming problem and its solution.

MODULE III: Inventory models: Deterministic models, Single item static models, models with price breaks and storage limitation, probabilistic models with single period and multi periods.

MODULE IV: Queuing theory: Basic structure, Role of the Poisson and exponential distributions.

M|M|1, M|M|C, M|Ek|1 and M|G|1 queues and their properties. Waiting time distributions, Steady
state solution.

MODULE V: Replacement problem: Replacement of items that deteriorate with time and money value change (i) change with time (ii) does not change with time, Individual replacement policy, Group replacement policy, Sequencing problem, Dynamic programming problem, Recursive approach.

REFERENCES

- Gass, S.I. (1969): Linear Programming Problem, Mc Graw Hill.
- Gross, D. and Harris, C.M. (1974): Fundamental of Queuing Theory, John Wiley.
- Hillier, F.S. and Leiberman, G.J. (1962): Introduction to Operations Research, Holden Day.
- Kanti Swarup, Manmohan and Gupta, M.M. (1985): Operations Research, Sultan Chand & Sons.
- Mittal, K.V. (1990): Optimization Methods.
- Ravindran, A, Philips, D.T. and Soleberg, J.J. (1997): Operations Research – Principles and Practise.
- Saaty, T.L. (1961): Elements of Queuing Theory with Applications, Mc Graw Hill.
- Taha, H.A. (1997): Operations Research, Mc.Millian.

SEMESTER **:** IV
COURSE CODE **:** STA-DE-544(ii)
COURSE TITLE **:** BAYESIAN INFERENCE
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Use relative frequencies to estimate probabilities.

CO2. Calculate conditional probabilities

CO3. Calculate posterior probabilities using Bayes' theorem.

CO4. Calculate simple likelihood functions

CO5. Describe the role of the posterior distribution, the likelihood function and the posterior distribution in Bayesian inference about a parameter.

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy level
Module 1	M01. Explain prior distribution M02. Interpret Bayes theorem and articulate to find posterior distribution.	Understand Apply
Module 2	M01. Find conjugate family of prior for a model M02. Choose appropriate member of conjugate prior for a family MO3. Explain non-informative, improper and invariant priors MO4. Define Jeffrey's invariant prior	Evaluate Apply Understand Understand
Module 3	MO1. Explain different types of loss function. MO2. Evaluate the estimate in terms of posterior risk	Understand Evaluate
Module 4	MO1. Explain Bayesian interval estimation MO2. Explain highest posterior density regions MO3. Interpret confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval	Understand Understand Apply
Module 5	M01. Explain testing of hypothesis in Bayesian analysis M02. Distinguish prior and posterior odds. M02. Establish Lindley's Paradox for testing a point hypothesis for normal mean against the two-sided alternative hypothesis.	Understand Remember Remember

COURSE CONTENT

MODULE I: Subjective interpretation of probability in terms of fair odds. Evaluation of (i) subjective probability of an event using a subjectively unbiased coin (ii) subjective prior distribution of a parameter. Bayes theorem and computation of the posterior distribution.

MODULE II: Natural Conjugate family of priors for a model. Hyper parameters of a prior from conjugate family. Conjugate families for (i) exponential family models, (ii) models admitting sufficient statistics of fixed dimension. Enlarging the natural conjugate family by (i) enlarging hyper parameter space (ii) mixtures from conjugate family, choosing an appropriate member of conjugate prior family. Non-informative, improper and invariant priors. Jeffrey's invariant prior.

MODULE III: Bayesian point estimation: as a prediction problem from posterior distribution.

Bayes estimators for (i) absolute error loss (ii) squared error loss (iii) 0 - 1 loss. Generalization to convex loss functions. Evaluation of the estimate in terms of the posterior risk.

MODULE IV: Bayesian interval estimation: Credible intervals. Highest posterior density regions.
Interpretation of the confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval.

MODULE V: Bayesian testing of Hypothesis: Specification of the appropriate form of the prior distribution for a Bayesian testing of hypothesis problem. Prior odds, Posterior odds, Bayes factor for various types of testing hypothesis problems depending upon whether the null hypothesis and the alternative hypothesis are simple or composite. Specification of the Bayes tests in the above cases. Discussion of Lindley's paradox for testing a point hypothesis for normal mean against the two-sided alternative hypothesis.

REFERENCES

- Berger, J. O. (1980): Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
- Bernando, J. M. and Smith, A. F. M. (1994): Bayesian Theory, Jolm Wiley and Sons.
- DeGroot, M. H. (1970): Optimal Statistical Decisions, McGraw Hill.
- Gemerman, D. (1997): Markov Chain Monte Carlo Stochastic Simulation for Bayesian Inference, Chapman Hall.
- Leonard, T. and Hsu, J. S. J. (1999): Bayesian Methods, Cambridge University Press.
- Robert, C. P. (1994): The Bayesian Choice: A decision Theoretic Motivation, Springer.

SEMESTER **:** IV
COURSE CODE **:** STA-DE-544(iii)
COURSE TITLE **:** ORDER STATISTICS
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Understand the basic properties of Order statistics.

CO2. Explain Probability mass function of order statistics arising from discrete and distributions.

CO3. Examine order statics of various types of discrete and continuous distributions

CO4.Explains the properties and relations of moments of Oder statistics.

CO5. Realize the difference between discrete and continuous probability distributions.

CO6. Explain the estimation and prediction under Order statistics.

CO7. Explain the concept of order statistics and solving problems related to it

CO8. Understanding concept of Record value and Concomitant Order statistics and their applications

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy level
Module 1	M01. Explains the basic concepts of distribution of single order statistic, joint distribution of two or more order statistics. M02. Verify the Markov property of Order statistics. M30. Examine the various properties of Order statistics. M04. . Explain the concept of order statistics	Understand Apply Remember Remember
Module 2	M01. Explain the moments of order statistic and its properties. M02. Derive the recurrence relations on the single and product moments of order statistics. M03. Describe Order statistics from symmetric population.	Understand Remember Remember
Module 3	M01. Examine order statics of various types of discrete and continuous distributions and articulate their properties	Apply
Module 4	M01. Explain the different estimators used in order statistics M02.Examine prediction of order statistics. M03. Find the confidence interval using sample quantile.	Remember Apply Analysis
Module 5	M01. Explains the concept of Record value and its application. M02. Explains the concept of Concomitant Order statistics and application	Understand Understand

COURSE CONTENT

MODULE I: Basic distribution theory: Distribution of single order statistic, joint distribution of two or more order statistics, conditional distributions and Markov chain property. Distribution of median, range and mid-ranges, Probability mass function of order statistics arising from discrete

distributions.

MODULE II: Moments of order statistics, Identities on the moments of order statistics, recurrence relations on the single and product moments of order statistics. Discussion of the above relation for symmetric population.

MODULE III: Order statistics from specific population such as Bernoulli and three point discrete
uniform distribution, exponential distribution, uniform, power function, normal and logistic distributions.

MODULE IV: Order statistics in statistical inference: Order statistics and sufficiency, linear estimations of location and scale parameters, Gupta's simplified linear estimator, prediction of order statistics, confidence intervals using sample quantile.

MODULE V: Record values: Definition and distribution theory of record values, prediction of future records and applications. Concomitants of order statistics: basic distribution theory and illustrations using bivariate samples arising from Morgenstern Family of Distributions. Applications of concomitants of order statistics.

REFERENCES

- Arnold, B. C. and Balakrishnan, N. (1989) : Relations, Bounds and Approximations for order statistics, Lecture notes in Statistics No. 53, Springer- Verlag, New York.
- Arnold, B. C., Balakrishnan, N. and Nagaraja, H. N. (1992) : A first course in Order Statistics, John Wiley, New York.
- David, H. A. and Nagaraja, H. N. (2003): Order statistics, 3rd edition, John Wiley, New York.
- Sarhan, A. E. and Greenberg, B. G. (1962): Contributions to Order Statistics, John Wiley, New York.

SEMESTER **:** IV
COURSE CODE **:** STA-DE-545(i)
COURSE TITLE **:** REGRESSION ANALYSIS AND ECONOMETRIC METHODS
CREDITS **:** 4

COURSE OUTCOMES

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

CO1: Describe simple and multiple linear regression models and its properties
CO2: Apply principle of least square method to estimate the parameters in simple and multiple linear regression models.
CO3: Identify multicollinearity problem, its consequences.

CO4: Discuss the problem of estimation of parameters when multicollinearity occurs.
CO5: Explain the Farrar –Glauber test for multicollinearity.
CO6: Describe Aitken generalized least square method of estimation.
CO7: Identify heteroscedastic disturbance.
CO8: Explain Gold field and Quandt test and Glesjer test.
CO9: Identify auto correlation and its consequences.
CO10: Explain the consequence of the presence of error in variables while estimating the parameters of a structural equation.
CO11: Discuss ILS, 2SLS, least variance ratio, full-information maximum likelihood and 3SLS method of estimation.
CO12: Perform identification problem in econometrics.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy level**
Module 1	MO1. Explain simple linear regression model MO2. Describe least square estimators MO3. Articulate to inference regarding regression parameters MO4. Explain ANOVA	Understand Remember Apply Understand
Module 2	MO1. Explain multiple linear regression models MO2. Explain inference regarding multiple regression parameters MO3. Explain Polynomial Regression models	Understand Analysis Understand
Module 3	MO1. Establish the scope of econometrics MO2. Explain general linear regression model MO3. Explain multicollinearity MO4. State and prove Farrar-Glauber test for multicollinearity.	Evaluate Understand Understad Remember
Module 4	MO1. Explain Heteroscedasticity MO2. Explain test for homogeneity of variances MO3. Explain auto-correlation	Understand Understand Understand
Module 5	MO1. Explain estimation in simultaneous equation model MO2. Establish 2 SLS estimation and 3 SLS estimation MO3. Discuss identification problems	Understand Apply Apply

COURSE CONTENT

MODULE I: Simple linear regression models, Assumptions of the linear stochastic regression model, Least square estimators, Properties of the least square estimates, Inference on regression parameters, Analysis of variance, Prediction.

MODULE II: Multiple linear regression models, Estimation of the model parameters, Testing in multiple regression, Confidence intervals in multiple regression, Prediction of new observations. Polynomial Regression models.

MODULE III: Definition and scope of econometrics, Methodology of econometric analysis, General linear regression model – Linear restrictions, significance test and confidence intervals, Multicollinearity problem - meaning, consequences, detection, estimation of parameters, Farrar-Glauber test for multicollinearity.

MODULE IV: Generalized least squares (GLS) method of estimation (Aitken), Heteroscedastic disturbances, Pure and mixed estimation, Test for homogeneity of variances, Gold field and Quandt test, Glesjer test, Auto correlation-meaning, sources and consequences, Tests for autocorrelation – Durbin Watson, Von-Neumann , Errors in variables, Dummy variables, Lagged variables, Linear regression with stochastic regressors, Instrumental variable estimation.

MODULE V: Estimation in simultaneous equation model, Recursive systems, Structural and reduced forms, Indirect least squares (ILS), 2 SLS estimation , 3 SLS estimation, Identification problem, Restrictions on structural parameters-rank and order conditions, Restrictions on variances and covariances, Full-Information maximum likelihood method.

REFERENCES

- Apte, P.G. (1990): Text book of Econometrics, Tata Mc Graw Hill.
- Gujarati, D (1979): Basic Econometrics, McGraw Hill.
- Johnston, J. (1984): Econometric Models, Third edition, McGraw Hill.
- Koutsoyiannis, A (1979): Theory of Econometrics, Macmillian Press.
- Montgomery, D.C., Peck, E.A. and Vining, G.G. (2007): Introduction to Linear Regression Analysis, John Wiley, India.
- Theil, H. (1982): Introduction to the Theory and Practice of Econometrics, John Wiley.
- Wetherill, G.B. (1986): Regression Analysis with Application, Chapman Hall.

SEMESTER **:** IV
COURSE CODE **:** STA-DE-545(ii)
COURSE TITLE **:** ACTUARIAL STATISTICS
CREDITS **:** 4

COURSE OUTCOMES

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

CO1. Develop a greater understanding of statistical principles and their application in actuarial statistics.

CO2. Describe the core areas of actuarial practice and relate to those areas actuarial principles, theories and models.

CO3. Describe estimation procedures for lifetime distributions.

CO4 Explain the concept of survival models.

CO5. Understand the application of knowledge of the life insurance environment.

CO6. Describe Net premiums and its various types.

CO7. Expand their applied knowledge in various specialized areas of actuarial studies and statistics.

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy level
Module 1	M01. Explains the utility theory and insurance. M02. Explain survival function and application. M30. Examine the properties of force of mortality. M04 Define Life tables and its relation with survival function, examples.	
Module 2	M01.Explain Multiple life functions and its properties. M02. Articulate the insurance and annuity benefits through multiple life functions evaluation for special mortality laws. M03. Explains the Multiple decrement tables. M04.Describe net single premiums and their numerical evaluations.	
Module 3	M01.Define Distribution of aggregate claims . M02. Derive the compound Poisson distribution and explain its applications. M03. Explain Principles of compound interest and its attributes.	
Module 4	M01. Explain the Life insurance and its types. M02 : Describe Insurance payable at the moment of death and at the end of the year of death-level benefit insurance M03. Explain the Life annuities and its types.	
Module 5	M01. Explain Net premiums and its importance M02. Distinguish between Continuous and discrete premiums	

	M03. Accumulation type benefits.	

COURSE CONTENT

MODULE I: Utility theory, insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality. Life tables and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

MODULE II: Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement tables, central rates of multiples decrement, net single premiums and their numerical evaluations.

MODULE III: Distribution of aggregate claims, compound Poisson distribution and its applications. Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

MODULE IV: Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, differed insurance and varying benefit insurance, recursions, commutation functions. Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities immediate and apportion able annuities-due.

MODULE V: Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportion able premiums, commutation functions, accumulation type benefits. payment premiums, apportion able premiums, commutation functions, accumulation type benefits.

REFERENCES

- Beard, R.E., Penlikainen, T. and Pesonnen, E (1984): Risk Theory: The Stochastic Basis of Insurance, 3rd Edition, Chapman and Hall, Londan.
- Bowers, N.L., Gerber, H.U., Hickman, J.E., Jones, D.A. and Nesbitt, C.J. (1997): ' Actuarial Mathematics', Society of Actuarias, Ithaca, Illiois, U.S.A., second Edition.
- Neill, A. (1977): Life Contingencies, Heineman.

SEMESTER **:** IV
COURSE CODE **:** STA-DE-545(iii)
COURSE TITLE **:** BIOSTATISTICS

CREDITS : 4

COURSE OUTCOMES

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

CO1. Understand the principal concepts about biostatistics.

CO2. Recognize the definition and the relation with real life applications.

CO3. Interpret data via various existing distributions.

CO4. Predict statistical decision through hypothesis testing.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy level**
Module 1	M01. Distinguish various type of survival distributions and their survival time. M02. Familiar with different test procedures and comparison of two survival distribution.	Understand Remember
Module 2	M01. Explain and exemplify the concept of censoring methods. M02. Evaluate the biological examples with different type of censoring.	Understand Evaluate
Module 3	M01. Articulate the concept of risk theory. M02. Explain indices for measurement of probability of death under competing risks and inter-relation. M03. Evaluate various methods of estimation under competing risk theory. M04. Distinguish independent and dependent risks.	Apply Understand Evaluate Remember
Module 4	M01. Explain basic biological concepts in genetics. M02. Describe Mendel's law. M03. Explain mutation and genetic drift. M04. Discuss and estimate linkage in heredity.	Understand Remember Understand Apply
Module 5	M01. Explain different Phases of clinical trials. M02. Describe designs for comparative trials. M03. Express sample size in a fixed sample design.	Understand Apply Apply

COURSE CONTENT

MODULE I: Functions of survival time, survival distributions and their applications viz. Exponential, Gamma, Weibull, Rayleigh, Lognormal, death density function for a distribution having bathtub shape hazard function. Tests of goodness of fit for survival distributions (WE test for exponential distribution, W -test for lognormal distribution, Chi-square test for uncensored observations). Parametric methods for comparing two survival distributions viz. L.R test, Cox's F-test.

MODULE II: Type I, Type II and progressive or random censoring with biological examples, Estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples. Non-parametric methods for estimating survival function and variance of the estimator viz. Actuarial and Kaplan -Meier methods.

MODULE III: Competing risk theory, Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death under competing risks by maximum likelihood and modified minimum Chi-square methods. Theory of independent and dependent risks. Bivariate normal dependent risk model. Conditional death density functions. Stochastic epidemic models: Simple and general epidemic models (by use of random variable technique).

MODULE IV: Basic biological concepts in genetics, Mendel's law, Hardy- Weinberg equilibrium, random mating, distribution of allele frequency (dominant/co-dominant cases), Approach to equilibrium for X-linked genes, natural selection, mutation, genetic drift, equilibrium when both natural selection and mutation are operative, detection and estimation of linkage in heredity.

MODULE V: Planning and design of clinical trials, Phase I, II, and III trials. Consideration in planning a clinical trial, designs for comparative trials. Sample size determination in fixed sample designs.

REFERENCES

- Biswas, S. (1995): Applied Stochastic Processes. A Biostatistical and Population Oriented Approach, Wiley Eastern Ltd.
- Cox, D.R and Oakes, D. (1984): Analysis of Survival Data, Chapman and Hall.
- Elandt, RC. and Johnson (1975): Probability Models and Statistical Methods in Genetics, John Wiley & Sons.
- Ewens, W. J. (1979): Mathematics of Population Genetics, Springer Verlag.
- Ewens, W. J. and Grant, G.R (2001): Statistical methods in Bioinformatics: An Introduction, Springer.
- Friedman, L.M., Furburg, C. and DeMets, D.L. (1998): Fundamentals of Clinical Trials, Springer Verlag.
- Gross, A. J. and Clark, V.A. (1975): Survival Distribution; Reliability Applications in

Biomedical Sciences, John Wiley & Sons.

SEMESTER **:** IV
COURSE CODE **:** STA-CC-546
COURSE TITLE **:** DISSERTATION
CREDITS **:** 4

Course Outcomes

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

CO1. study and examine data thoroughly and comprehensively towards attaining precision both in detail and in depth.

CO2. Conducts research and analysis crucial to substantiate the report.

SEMESTER **:** II
COURSE CODE **:** STA-GC-521
COURSE TITLE **:** ELEMENTS OF PROBABILITY THEORY
CREDITS **:** 2

COURSE OUTCOMES

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

C01. Explain probability space
C02. Evaluate limits of sequence of events
C03. State and prove Bayes theorem.
C04. Explain random variables
C05. Distinguish probability distribution and distribution function
C06. Explain properties of distribution
C07. Calculate expectation and moments of various random variables.
C08. Explain the concept of convergence and check for the of convergence of a given sequences of random variables.
C09. Find the expressions for the characteristic function of a random variable and verify its properties
CO10. Apply the various laws of large numbers to sequences of random variables

MODULE OUTCOMES

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy Level
Module 1.	M01. Explain probability space and limits of sequence of random variance M02. State and prove monotone and continuity properties of probability measure. M03. Explain addition theorem MO4. State and prove Borel-Cantelli Lemma MO5. Explain conditional probability and Bayes theorem	Understand Remember Understand Remember Apply
Module: 2	M01. Explain random variables M02. Explain properties of distribution function M03. Describe moments and articulate to problems related to moments MO4. State Markov and Liaponov inequality	Understand Evaluate Analysis Remember
Module 3	MO1. Explain characteristic function and its properties MO2. Explain inversion theorem on distribution function MO3. Distinguish continuity theorem and Bochner-Khintchines theorem of characteristic function	Understand Understand Remember
Module 4	MO1. Explain convergence of sequence of random variables MO2. Apply the concepts of convergence to sequence of random distributions.	Understand Apply
Module 5	MO1. State and prove various laws of large numbers MO2. Apply various laws to sequence of random variables	Remember Apply

COURSE CONTENT

MODULE I: Probability space, limit of sequence of events, monotone and continuity properties of probability measure, addition theorem, independence of finite number of events, sequence of events, Borel-Cantelli lemma, Borel zero one law. Conditional Probability and Bayes Theorem.

MODULE II: Random variable, its probability distribution and distribution function, properties of distribution function, expectation and moments of random variables, Markov and Liaponov inequalities.

MODULE III: Characteristic function and their elementary properties, uniform continuity and non-negative definiteness of characteristic function, inversion theorem (proof not required), uniqueness theorem, Fourier inversion theorem, continuity theorem (proof not required), Bochner-Khintchine theorem of characteristic functions(proof not required).

MODULE IV: Stochastic convergence of sequence of random variables:- convergence in distribution, convergence in probability, almost sure convergence and convergence in the r-th mean, their interrelationships.

MODULE V: Stochastic convergence of series of random variables:-Law of large numbers, weak law of large numbers: Bernoulli, Chebyshev & Khintchine, Kolmogorov inequality, strong law of large numbers: Kolmogorov- iid & non-iid cases (proof not required), central limit theorem: Demoiver-Laplace, Liapounov (without proof), Lindberg-Feller (without proof).

REFERENCES

- Bhat, B.R. (1985): Modern Probability Theory: An Introductory Text Book, 2nd edition, Wiley Eastern.
- Gnedenoko, B.V. (1969): The Theory of Probability, Mir Publishers, Moscow.
- Laha, R.G. and Rohatgi, V.K. (1979) : Probability Theory, John Wiley, New York
- Loeve, M. (1968): Probability Theory, D.Van Nostrand Co.Inc., Princeton, New Jersey.
- Pakshirajan, R.P. (1983): Converse of Central Limit Theorem, Journal of the Kerala Statistical Association.

SEMESTER **:** III
COURSE CODE **:** STA-GC-531
COURSE TITLE **:** ELEMENTARY STATISTICAL METHODS
CREDITS **:** 2

COURSE OUTCOMES

On completion of the course, students should be able to:
C01. Calculate the various measures of central tendency and dispersion, correlation coefficient, regression equations etc.
C02. Fit various regression equations to data sets
C03. Explain the concepts of statistical surveys, sampling, census and various sampling methods
C04. Prepare a questionnaire and conduct a sample survey
C05. Articulate the concepts of random variable and random distributions
C06. Describe the properties of various standard distributions and sampling distributions
C07. Conduct tests of significance for population mean(s), variance(s) (one and two samples), F-test, Testing the significance of a correlation coefficient.
C08. Carry out Chi square test of goodness of fit and testing independence of attributes. Analysis of variance - One way and two-way classifications.

Module Outcomes

Sl. No:	Outcomes On completion of each module, students should be able to:	Taxonomy Level

Module 1.	M01. Calculate the Measures of central tendency and dispersion M02. Find out the coefficient of correlation and regression equations for given data sets. M03. Fit appropriate regression equations to data sets	Apply Apply Create
Module: 2	M01. Articulate concepts of statistical surveys, sampling and census M02. Distinguish between the three methods of sampling M03. Design a sample survey and carry out the survey	Understand Analysis Create
Module 3	M01. Articulate concepts of random variables, their properties and functions of random variables M02. Describe and distinguish between the various standard distributions and sampling distributions like Binomial, Poisson and Normal. t, F and Chi square. M03. Derive the various functions of distributions like Binomial, Poisson and Normal. t, F and Chi square. M04. Solve various problems associated with distributions like Binomial, Poisson and Normal. t, F and Chi square. M05. Fit Poisson, binomial and normal distributions to data sets	Understand Apply Evaluate Evaluate Apply
Module 4	M01. Describe various tests of significance and concepts of statistical inference: standard large sample tests and small sample tests, tests for population mean(s), variance(s) (one and two samples), F-test, Testing the significance of a correlation coefficient. M02: Test the various hypothesis associated with standard large sample tests and small sample tests, tests for population mean(s), variance(s) (one and two samples), F-test, Testing the significance of a correlation coefficient. M03. Design tests of hypotheses dealing with standard large sample tests and small sample tests, tests for population mean(s), variance(s) (one and two samples), F-test, Testing the significance of a correlation coefficient.	Understand Apply Create
Module 5	M01. Explain the various concepts of Chi square test of goodness of fit. Contingency tables and testing independence of attributes. Analysis of variance - One way and two way classifications. M02. Carry out tests based on Chi square test of goodness of fit. and testing independence of attributes; Analysis of variance - One way and two-way classifications. M03. Design a test of hypothesis for testing the Chi square test of goodness of fit. Contingency tables and testing independence of attributes. Analysis of variance - One way and two way classifications.	Understand Apply Create

COURSE CONTENT

MODULE I: Measures of central tendency and dispersion. Correlation and Regression. Least squares method of curve fitting.

MODULE II: Statistical surveys, Sampling and census, Important methods of sampling – Simple random, Systematic and Stratified sampling.

MODULE III: Random variables, Expectation and variance of random variables. Basic distributions: Binomial, Poisson and Normal. Sampling distributions: t, F and Chi square.

MODULE IV: Test of significance, basic concepts of statistical inference, standard large sample tests and small sample tests, tests for population mean(s), variance(s) (one and two samples), F-test, Testing the significance of a correlation coefficient.

MODULE V: Chi square test of goodness of fit. Contingency tables and testing independence of attributes. Analysis of variance - One way and two way classifications.

REFERENCES

- Cochran , W.G. (1977). Sampling Techniques, Wiley Eastern Ltd.
- Johnson ,N.L. and Kotz,S. (1969) Distributions in Statistics; Discrete distributions. John Wiley and Sons ,New York.
- Johnson ,N.L. . Kotz,S. and Balakrishnan, N (1994)Continuous Univariate Distributions - 1 , 2nd Edition John Wiley and Sons ,New York.
- Johnson ,N.L. . and Kotz,S. (1995) Continuous Univariate Distributions -2 ,2nd Edition, John Wiley and Sons ,New York.
- Murthy, M. N. (1967). Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
- Rohatgi,V.K.(1990) An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd.
- Singh, D. and Chaudhary, F.S. (1986). Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd.