DEPARTMENT OF STATISTICS

UNIVERSITY OF KERALA

Outcomes Based Syllabus (OBS)

of

MASTER OF SCIENCE IN STATISTICS

(Effective from Academic Year 2024-25)

UNIVERSITY OF KERALA

कर्मणि व्यज्यते प्रज्ञा

NAAC A++ Grade

UNIVERSITY OF KERALA

One of the first **16** Universities in India, the University of Kerala was founded as the University of Travancore in the erstwhile princely state of Travancore by his highness Sri. Chithira Thirunal Maharaja in **1937**. At present, the University has **16** faculties and **44** departments of teaching and research in addition to study centers and other departments. The Manuscript Library of the University is a treasure trove of Indian culture. The library has over 65,000 works in 30,000 copies mainly of palm leaf manuscripts, in addition to paper manuscripts, copper plates, birch bark and textiles, which includes those belonging to Burma, Malaysia, Indonesia, Nepal etc. The Adult Education Department of the University has received UNESCO-NLM award in 2005. The University Library established in 1942 has over 3,00,000 books and gives access to over 9000 on-line journals. The University has published an English translation of the classic Dutch work, "Hortus Malabaricus" a 20-volume treatise on plant wealth of Kerala, in 2003. University of Kerala has been accredited by NAAC (UGC) with **A++** Grade in the third cycle. University of Kerala was ranked **40** in **NIRF** (National Institutional Ranking Framework) 2022 conducted by the Ministry of Human Resource Development, Government of India, at the national level.

This department is the **second oldest post-graduate department of Statistics in India**, established in **1945** based on the recommendation of a committee consisting of eminent members including Prof. P. C. Mahalanobis. The post-graduate Department of Statistics, University of Kerala has played a crucial role in the dissemination of advanced knowledge in Statistics and in the propagation of the studies in Statistics. Apart from imparting training in advanced topics of Statistics to its students, the department has been also catering the Statistical requirements of the Govt. of Kerala. Dr. U. S. Nair was the Founder Professor of this department followed by eminent successors Dr. Aleyamma George, Dr. R. Krishna Pillai, Dr. R. Ramakumar, Prof. P. S. J. Nair, Dr. Jacob Sundara Raja, Dr. R. N. Pillai, Dr. T. S. K. Moothathu, Dr. P. Yageen Thomas, Dr. G. Lesitha, Dr. C. Satheesh Kumar, Dr. E. I. Abdul Sathar and Dr. Manoj Chacko. The Department of Science and Technology (DST), New Delhi has identified this department under its FIST Programme. This department has moulded several reputed statisticians like Prof. K. C. S. Pillai, Prof. A. M. Mathai, Prof. Thomas Mathew and so on. Research papers are published regularly from this department in refereed journals in Statistics and have been extensively cited in the latest Statistical publications.

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

On completion of the programme, students should be able to:	
PSO1	Apply statistical theory and its applications in various fields
PSO2	Describe recent developments in statistical theory and practice
PSO3	Apply statistical theory and methodologies to analyze and interpret data encountered in day-to-day life situations
PSO4	Apply statistical reasoning and problem-solving techniques to address research questions and real-world problems in various domains
PSO5	Prepare clear and concise reports, presentations, and visualizations to communicate statistical results and insights
PSO6	Design and conduct statistical experiments, surveys, and studies to investigate hypotheses and test theories

Structure of the M.Sc. Statistics Programme

Sem. No.	Course code	Name of the Course	Number of Credits	Marks	
				CA	ESA
I	STA-CC-511	Mathematical Methods	4	40	60
I	STA-CC-512	Distribution Theory	4	40	60
I	STA-CC-513	Sampling Theory	4	40	60
I	STA-CC-514	Measure Theory	4	40	60
I	STA-CC-515	Statistical Computing using R and Python	4	40	60
II	STA-CC-521	Design and Analysis of Experiments	4	40	60
II	STA-CC-522	Multivariate Analysis	4	40	60
II	STA-CC-523	Probability Theory	4	40	60
II	STA-CC-524	Theory of Estimation	4	40	60
III	STA-CC-531	Stochastic Processes	4	40	60
III	STA-CC-532	Time Series Analysis	4	40	60
III	STA-CC-533	Testing of Hypotheses	4	40	60
III	STA-DE-534(i)	Applied Regression Analysis	4	40	60
III	STA-DE-534(ii)	Actuarial Statistics	4	40	60
III	STA-DE-534(iii)	Biostatistics	4	40	60
IV	STA-CC-541	Practical	4	40	60
IV	STA-DE-542(i)	Statistical Quality Control and Reliability Modeling	4	40	60
IV	STA-DE-542(ii)	Advanced Probability Theory	4	40	60
IV	STA-DE-542(iii)	Data Mining and their Applications	4	40	60
IV	STA-DE-543(i)	Operations Research	4	40	60
IV	STA-DE-543(ii)	Bayesian Inference	4	40	60
IV	STA-DE-543(iii)	Order Statistics	4	40	60
IV	STA-CC-544	Dissertation/ Project & Viva	8		100

Generic Course (GC)

Course code	Name of the Course	Number of Credits	Marks	
			CA	ESA
STA-GC-501	Introduction to Data Analytics with R	2	40	60
STA-GC-502	Elementary Statistical Methods	2	40	60
STA-GC-503	Elements of Probability Theory	2	40	60

STA - Statistics

CC - Core Course

DE - Discipline Specific Elective

GC - Generic Course

CA Marks (40) distributed as follows

Mid Semester Examination	20 Marks
Assignment	10 Marks
Seminar	10 Marks

SEMESTER : I
COURSE CODE : STA-CC-511
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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. To be familiar with the idea of open and closed set	Understand
	Find the limit point of a sequence	Evaluate
	State and prove Hein-Boral theorem	Remember
Module 2	MO1. Find the limit and continuity of a given function	Apply
	MO2. Find the conditional maximum and minimum of a given function	Apply
	Verify generalized mean value theorem to a given function	Analyse
Module 3	MO1. Write the Riemann integral of the given function	Apply
	MO2. State and prove Fubini's theorem	Remember
Module 4	MO1. Find the rank of a given matrix	Evaluate
	MO2. Understand the concept of determinants and its properties	Understand
	MO3. Solve the system of linear equations	Apply
Module 5	MO1. Determine the Eigen values and Eigen vectors of the given matrix	Evaluate
	MO2. Obtain the diagonal form and triangular form of a given matrix	Apply
	MO3. Write down the spectral decomposition of the given matrix	Evaluate
Module 6	MO1. Find the nature of the quadratic form	Analyse
	MO2. Articulate the concept of generalized inverse	Understand

	MO3. Obtain the g-inverse and Moore- Penrose g-inverse of the given matrix	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

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

SEMESTER : I
COURSE CODE : STA-CC-512
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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explains the basic concepts of pgf, mgf and characteristic functions	Understand
	MO2. Examine various types of discrete and continuous distributions and articulate their properties	Analyse
	M30. Examine the various properties of probability distribution	Evaluate
	MO4. Solving problems related to several distributions	Apply
Module 2	MO1. Examine various types of discrete and continuous distributions and articulate their properties	Analyse
	MO2. Examine the various properties of probability distribution	Evaluate
	MO3. Solving problems related to several distributions	Apply
Module 3	MO1. Finding the joint, marginal and conditional pdf of a bivariate distribution	Understand
	MO2. Articulate the various concepts of Conditional expectation and conditional variance	Analyse
	MO3. Explains the concept of pgf, mgf and independence of a bivariate random vector	Remember
	MO4. Articulate Multinomial and bivariate normal distributions and their properties in detail	Apply

Module 4	MO1. Apply transformation of variable technique for finding the distribution of functions of random variables	Apply
	MO2. Derive the distributions of sum, product and ratios of random variables	Analyse
Module 5	MO1. Explain the concept of order statistics	Understand
	MO2. Find the joint distribution of two order statistics	Evaluate
	MO3. Calculate Distribution of functions of two order statistics	Apply
Module 6	MO1. Explains different sampling distributions	Understand
	MO2. Find expressions for probability density function of sampling distribution	Apply
	MO3. Distinguish between partial and multiple correlation coefficient	Apply
	MO4. Finding the Distribution of empirical distribution function	Evaluate

COURSE CONTENT

MODULE I: Basic concepts in distribution theory: p.g.f., m.g.f., and characteristic function. Univariate discrete distributions: Binomial, Negative Binomial, Poisson, Hyper geometric, Geometric.

MODULE II: Univariate continuous distributions: Beta type I, Beta type II, Gamma, Normal, Log-Normal, Pareto, Weibull, Cauchy. Laplace, Logistic, Log-logistic. Rayleigh and generalized exponential distributions.

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

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

MODULE VI: Sampling distributions: Chi-square, t distribution, and F distributions (both central and non-central) and their applications, Empirical distribution; Distribution of empirical distribution function. Correlation and regression; simple partial and multiple correlation coefficients.

REFERENCES

1. Anderson, T.W. (1984). An Introduction to Multivariate Statistical Analysis, Macmillan Publishing Company.

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

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

COURSE OUTCOMES

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

CO1	Distinguish between probability sampling and non-probability sampling.
CO2	Understand SRSWR and SRSWOR, estimate the population mean, population total, population proportion and variance.
CO3	Understand the concept of sampling with varying probabilities like Probability proportional to size (PPS) sampling and the procedure of selecting a PPS sample with and without replacement.
CO4	Explain Midzuno-Sen- Lahiri, Murthy's, DesRaj's sampling strategies under varying probability without replacement.
CO5	Familiar with the concept of stratified random sampling and various types of allocations.
CO6	Comparison of systematic sample, SRS and stratified random sample for a population with linear trend.
CO7	Explain the concept of Hartley-Ross unbiased ratio type estimator
CO8	Describe the regression estimator and its properties.
CO9	Understand the cluster sampling with equal and unequal clusters.
CO10	Find the relative efficiency of cluster as unit of sampling compared to a single element as unit of sampling.

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Use various procedures of selecting samples from the population	Apply
	MO2. Explain method of selecting samples using simple random sampling	Evaluate
	MO3. Articulate the estimation of population mean, total and proportion and hence the estimation of the standard error.	Apply
	MO4. Explain determination of sample size and confidence interval	Evaluate
Module 2	MO1. Explain PPS sampling and articulate to selection procedures using PPS with and without replacement	Evaluate
	MO2. Find methods to estimate population mean, total and variance with respect to PPS sampling	Apply
	MO3. Apply various selection procedures for selecting samples using PPS	Apply
Module 3	MO1. Explain the purpose of stratification	Evaluate
	MO2. Explain stratified random sampling	Understand
	MO3. Examine the various properties of stratified sampling	Evaluate
	MO4. Explain the concept of double sampling	Understand

	MO5. Discuss various allocation procedures	Analyse
Module 4	MO1. Explain systematic sampling	Understand
	MO2. Distinguish between single start linear systematic sampling and multiple start linear systematic sampling	Evaluate
	MO3. Describe the comparison of simple random sample, systematic sample and stratified sample for a population with linear trend	Understand
Module 5	MO1. Distinguish between ratio and regression estimators	Understand
	MO2. Explain various properties of ratio and regression estimators	Apply
	MO3. Discuss ratio and regression estimator for stratified population	Analyse
Module 6	MO1. Explain cluster sampling	Understand
	MO2. Distinguish between clusters of equal and unequal sizes	Remember
	MO3. Describe the two-stage cluster sampling of equal size and unequal size	Evaluate

COURSE CONTENT

MODULE I: Census, Sampling, Probability sampling and non-probability sampling. Simple random sampling with replacement and without replacement. Procedures of selection, Estimation of population mean, population total, population proportion and variance. Estimation of standard errors of these estimators. Confidence intervals. Determination of sample size.

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

1. Cochran, W.G. (1977). Sampling Techniques, Wiley Eastern Ltd.
2. Des Raj (1976). Sampling Theory. McGraw Hill.
3. Murthy, M. N. (1967). Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
4. Singh, D. and Chaudhary, F.S. (1986). Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd.
5. 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 : I
COURSE CODE : STA-CC-514
COURSE TITLE : MEASURE THEORY
CREDITS : 4

COURSE OUTCOMES

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

CO1	To be familiar with the concept of monotone classes
CO2	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	Explain the concept of convergence in a sequence of measurable functions
CO9	To be familiar with the concept of absolute continuity and singularity
CO10	Distinguish between the concept of uniform convergence and almost uniform convergence
CO11	To understand the concept of convergence in mean and convergence in pth mean
CO12	To be familiar with the concept of monotone classes

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain and exemplify the concepts of Boral field	Understand
	MO2. Understand the concept of classes of sets	Understand
	MO3. Give an example of monotone class	Apply
Module 2	MO1. State and prove Hahn-Jordan decomposition theorem	Remember
	MO2. Articulate the basic concept of measure	Understand
	MO3. Give an examples of measure like length, area and volume	Apply
Module 3	MO1. Explain various result associated with measurable functions	Remember
	MO2. To be familiar with complete measure	Understand
	MO3. Examine various properties of a probability measure	Analyse
Module 4	MO1. To be familiar with the definition and properties of integral	Understand
	MO2. Explain Lebesgue Stieltjes measure	Understand
	MO3. State and prove Fatou's lemma	Remember
Module 5	MO1. Understand the concept of product spaces and product measures	Understand
	MO2. To be familiar with the concept of absolute continuity and singularity	Understand
	MO3. State and prove Fubini's theorem	Remember
	MO1. Describe the concept of sequence of measurable functions	Remember

Module 6	MO2. Articulate the concept of uniform convergence and almost uniform convergence	Understand
	MO3. State and prove Egoroff's theorem	Remember

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: Set function, additive and countably additive set functions, Outer measure, measure and counting measure, Hahn - Jordan decompositions theorem, examples of measure like length, area and volume, additive set function on a ring.

MODULE III: Lebesgue measure, measurable set, non-measurable sets, complete measures, Lebesgue - Stieltjes measure, Measurable functions and properties, Borel measurability.

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: Product spaces and product measures, Fubini's theorem. absolute continuity and singularity, Lebesgue decomposition and Radon - Nikodym theorem, properties of Radon - Nikodym derivative.

MODULE VI: Sequences of measurable functions. Uniform convergence, almost uniform convergence, convergence a.e, Egoroff's theorem. Convergence in measure, convergence in mean, and convergence in pth mean.

REFERENCES

1. Bartle, R.G. (1996): The Elements of Integration and Lebesgue Measure, John Wiley and Sons. New York.
2. Kingman, J.F.C. and Taylor, S.J. (1977): Introduction to Measure and Probability, Cambridge University Press, Cambridge.
3. Roydon, H. L. (1968): Real Analysis, Macmillan, New York.
4. Rudin, W. (1970): Real and Complex Analysis, McGraw Hill Book Co., New York.

SEMESTER : **I**
COURSE CODE : **STA-CC-515**
COURSE TITLE : **STATISTICAL COMPUTING USING R AND PYTHON**
CREDITS : **4**

COURSE OUTCOMES

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

CO1	Utilize R and Python programming languages for statistical computing and data analysis
CO2	Apply fundamental programming concepts and syntax specific to R and Python environments
CO3	Perform data manipulation and analysis tasks, including subsetting, filtering, sorting, merging, reshaping, and summarizing data using both R and Python
CO4	Visualize data effectively using base graphics, ggplot2, Matplotlib, and Seaborn in R and Python
CO5	Develop and debug user-defined functions and control structures in R and Python
CO6	Implement advanced programming techniques such as object-oriented programming (OOP) and functional programming in both R and Python
CO7	Conduct basic statistical analyses including hypothesis testing, regression analysis, non-parametric tests, survival analysis, and time series analysis using appropriate libraries in R and Python

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Understand the basics of R programming language and its applications in data analysis	Remember
	MO2. Navigate the R environment and execute basic R syntax	Apply
	MO3. Manipulate R objects and data types, including vectors, matrices, arrays, data frames, and lists	Apply
	MO4. Perform data input/output operations, reading and writing data from/to different file formats	Apply
	MO5. Implement basic data manipulation techniques such as subsetting, filtering, sorting, merging, reshaping, and summarizing data	Apply
	MO6. Develop user-defined functions and control structures in R	Create
Module 2	MO1. Work with factors, dates, and times in R	Understand
	MO2. Create data visualizations using base R graphics and ggplot2	Apply
	MO3. Handle large datasets efficiently using data.table and dplyr packages	Apply
	MO4. Debug and profile R code for optimization	Analyze
	MO5. Understand and implement object-oriented programming principles in R	Understand

	MO6. Apply functional programming techniques using apply functions, lapply, sapply, and mapply	Apply
Module 3	MO1. Perform basic statistical analysis using built-in functions and libraries in R	Apply
	MO2. Conduct hypothesis testing and construct confidence intervals	Apply
	MO3. Implement regression analysis techniques including linear regression, logistic regression, and Poisson regression	Apply
	MO4. Conduct non-parametric tests and analysis of variance	Apply
	MO5. Perform survival analysis using Kaplan-Meier survival curves and Cox proportional hazards regression	Apply
	MO6. Apply time series analysis techniques such as ARIMA models and seasonal decomposition	Apply
Module 4	MO1. Understand the basics of Python programming language and its applications in data analysis	Remember
	MO2. Navigate the Python environment and execute basic Python syntax	Apply
	MO3. Manipulate Python objects and data types, including numbers, strings, lists, tuples, sets, and dictionaries	Apply
	MO4. Implement control structures such as if-else statements and loops	Apply
	MO5. Develop user-defined functions in Python	Create
	MO6. Perform input/output operations, reading and writing data from/to different file formats	Apply
Module 5	MO1. Work with Numpy arrays and Pandas data frames for data manipulation and analysis	Apply
	MO2. Visualize data using Matplotlib and Seaborn libraries in Python	Apply
	MO3. Debug and profile Python code for optimization	Analyze
	MO4. Understand and implement object-oriented programming principles in Python	Understand
	MO5. Introduce functional programming concepts in Python	Understand
Module 6	MO1. Conduct basic statistical analysis using built-in functions and libraries in Python	Apply
	MO2. Perform hypothesis testing and construct confidence intervals in Python	Apply
	MO3. Implement regression analysis techniques including linear regression, logistic regression, and Poisson regression in Python	Apply
	MO4. Conduct non-parametric tests and analysis of variance in Python	Apply
	MO5. Perform survival analysis using Kaplan-Meier survival curves and Cox proportional hazards regression in Python	Apply
	MO6. Apply time series analysis techniques such as ARIMA models and seasonal decomposition in Python	Apply

COURSE CONTENT

MODULE I: Introduction to R Programming: Overview of R and its uses in data analysis, Introduction to the R environment and basic R syntax, Working with R objects and data types (vectors, matrices, arrays, data frames, lists), Data input/output in R (reading/writing data from/to different file formats), Basic data manipulation and analysis in R (subsetting, filtering, sorting, merging, reshaping, summarizing, and visualizing data), Writing user-defined functions and control structures in R.

MODULE II: Advanced R Programming: Working with factors, dates, and times in R, Data visualization in R (using base R graphics and ggplot2), Working with large datasets in R (using data.table and dplyr) Debugging and profiling R code, Object-oriented programming in R (S3 and S4 classes). Introduction to functional programming in R (using apply functions, lapply, sapply, and mapply).

MODULE III: Statistical Analysis with R: Basic statistical analysis in R (using built-in functions and libraries such as stats and MASS), Hypothesis testing and confidence intervals in R, Regression analysis in R (linear regression, logistic regression, Poisson regression), Non-parametric tests and analysis of variance (ANOVA) in R, Survival analysis in R (Kaplan-Meier survival curves, Cox proportional hazards regression), Time series analysis in R (ARIMA models, seasonal decomposition of time series.

MODULE IV: Introduction to Python Programming: Overview of Python and its uses in data analysis, Introduction to the Python environment and basic Python syntax, Working with Python objects and data types (numbers, strings, lists, tuples, sets, dictionaries), Control structures in Python (if-else statements, loops), Writing user-defined functions in Python, Input/output in Python (reading/writing data from/to different file formats).

MODULE V: Advanced Python Programming: Working with Numpy arrays and Pandas data frames, Data manipulation and analysis in Python (subsetting, filtering, sorting, merging, reshaping, summarizing, and visualizing data), Data visualization in Python (using Matplotlib and Seaborn), Debugging and profiling Python code, Object-oriented programming in Python, Introduction to functional programming in Python.

MODULE VI: Statistical Analysis with Python: Basic statistical analysis in Python (using built-in functions and libraries such as Scipy and Statsmodels), Hypothesis testing and confidence intervals in Python, Regression analysis in Python (linear regression, logistic regression, Poisson regression), Non-parametric tests and analysis of variance (ANOVA) in Python, Survival analysis in Python (Kaplan-Meier survival curves, Cox proportional hazards regression), Time series analysis in Python (ARIMA models, seasonal decomposition of time series).

REFERENCES

1. Hadley Wickham and Garrett Grolemund (2017). *R for Data Science: Import, Tidy, Transform, Visualize, and Model Data*, O'Reilly Media, Inc.

2. Bradley C. Boehmke (2016). *Data Wrangling with R*, Springer.
3. Phil Spector (2008). *Data Manipulation with R*, Springer.
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5. Carson Sievert (2020). *Interactive Web-Based Data Visualization with R, plotly, and shiny*, Taylor and Francis.
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18. Andreas Muller (2016). *Introduction to Machine Learning with Python: A Guide for Data Scientists*, 1st edition, O'Reilly.
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SEMESTER : II
COURSE CODE : STA-CC-521
COURSE TITLE : DESIGN AND ANALYSIS OF EXPERIMENTS
CREDITS : 4

COURSE OUTCOMES

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

CO1	Identify estimability of a linear parametric function
CO2	Apply Gauss-Markov theorem for finding BLUE of a parametric function
CO3	Identify connected, balance and orthogonal designs
CO4	Perform one way and two-way analysis of variances
CO5	Design and analyse CRD, RBD, LSD and GLSD
CO6	Design and analyse factorial experiments
CO7	Apply principle of total and partial confounding in factorial experiments
CO8	Construct incomplete block design
CO9	Analyze BIBD and PBIBD
CO10	Perform analysis of covariance in one way and two-way classification.
CO11	Perform missing plot and mixed-up plots analysis in RBD and LSD
CO12	Estimate missing yields in split plot and BIBD

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1: Identify estimability of a linear parametric function	Understand
	MO2: Apply Gauss-Markov theorem for finding BLUE of a parametric function	Apply
	MO3: Formulate the model for one way and two-way classification	Understand
	MO4: Perform one way and two analysis of varaince	Analyze
Module 2	MO1: Identify connected, balance and orthogonal designs	Understand
	MO2: Design and analysis of CRD, RBD, LSD and GLSD	Analyze
Module 3	MO1: Design and analyse of 22, 3n and pn factorial experiments	Analyze
	MO2: Apply principle of total and partial confounding in factorial experiments	Apply
Module 4	MO1: Analyze BIBD with inter and intra block informations	Apply
	MO2: Analyse PBIBD with only two associates classes	Apply
Module 5	MO1: Analyses Split-plot and split-split plot designs	Apply
	MO2: Formulate the model for one way and two-way analysis of covariance	Apply
	MO3: Perform one way and two-way analysis of covariance	Apply
Module 6	MO1: Perform Missing plot analysis in RBD and LSD	Analyze
	MO3: Perform mixed-up plot analysis in RBD and LSD	Analyze
	MO2: Estimate missing yields in split plot and BIBD	Evaluate

COURSE CONTENT

MODULE I: General linear models, estimability of linear parametric functions, Gauss-Markov theorem, tests of linear hypothesis, one-way classification, two-way classification with equal and unequal number of observations per cell.

MODULE II: Randomization, replication and local control, Block designs- information matrix of block designs, criteria for connectedness, balance and orthogonality. Standard designs: CRD, RBD, LSD, GLSD. Efficiency of designs and comparison.

MODULE III: Factorial designs: Statistical analysis of symmetrical factorial designs. Total and partial confounding in 2n, 3n and pn 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

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SEMESTER : II
COURSE CODE : STA-CC-522
COURSE TITLE : MULTIVARIATE ANALYSIS
CREDITS : 4

COURSE OUTCOMES

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 Multivaraite data analysis

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1: Define the multivariate normal density function.	Understand
	MO2: Obtain the characteristic function of multivariate normal density	Understand
	MO3: Find the distribution of linear combination of multivariate normal random vector using characteristic function	Apply
	MO4: Find regression of multivariate normal distribution using conditional distribution	Apply
Module 2	MO1: Characterize quadratic forms of multivariate distribution	Apply
	MO2: Obtain the distribution of sums and quotients of quadratic forms	Apply
	MO3: Apply Cocharan's theorem to find distribution of quadratic forms of multivariate normal random vector	Apply
Module 3	MO1: Obtain the MLEs of mean and variance of multivariate normal distribution	Evaluate
	MO2: Find the characteristic function of Wishart distribution	Apply
	MO3: Show that Wishart distribution possess additive property	Understand
	MO4: Find the distribution of sample dispersion matrix	Apply
Module 4	MO1: Find the distribution of sample multiple correlation for multivariate normal distribution	Understand
	MO2: Find the distribution of sample partial correlation coefficients for multivariate normal distribution	Apply
	MO3: Obtain the distribution of test statistic for the test the significance of correlation coefficient and partial correlation coefficient	Apply

Module 5	MO1: Test the mean vector of a multivariate normal distribution	Apply
	MO2: Test the equality of means of two or more multivariate normal distributions	Apply
	MO3: Use Hotelling's T^2 and Mahalanobis D^2 statistics in testing hypothesis regarding multivariate normal distributions	Apply
	MO4: Find the relationship between Hotelling's T^2 and Mahalanobis D^2 statistics	Understand
Module 6	MO1: Perform principal component analysis and factor analysis	Analyze
	MO2: Classify individuals/items in to one of k multivariate normal populations	Analyze
	MO3: Identify canonical variables and quantify canonical correlation	Analyze

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

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5. Khatri, C.G. and Srivastava (1979): An Introduction to Multivariate Statistics, North – Holland, New York.
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7. Rao, C.R. (1973): Linear Statistical Inference and its Applications, Wiley Eastern, New York.
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SEMESTER : II
COURSE CODE : STA-CC-523
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
CO10	Apply the various laws of large numbers to sequences of random variables.

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain and exemplify the concepts of probability space	Understand
	MO2. Examine the various properties of a probability measure.	Analyse
	MO3. State and explain various results associated with probability measure	Understand
	MO4. Explain the concepts of independence of events	Remember
	MO5. Construct examples of independent events	Create
	MO6. Construct counter examples for proving/illustrating certain results associated with probability measure	Create
	MO7. Evaluate the conditional probability and verify its properties	Evaluate
	MO8. Articulate the Bayes theorem and apply it to calculate apriori probabilities	Apply
Module 2	MO1. Distinguish between various types of random variables and articulate their properties	Apply
	MO2. Describe the various functions of random variables and find the functions for various random variables	Apply
	MO3. Explain and exemplify the concepts of decomposition of distribution function of a random variable	Understand
	MO4. Articulate/exemplify various types of distributions and their important properties	Understand
Module 3	MO1. Calculate the mathematical expectation, moments and generating functions of random variables	Evaluate

	MO2. Explain the concepts of random vectors and distribution function of random vectors, and their important properties	Understand
	MO3. Articulate the various moment inequalities	Understand
	MO4. Apply the various moment inequalities to various distributions	Apply
Module 4	MO1. Articulate and appraise stochastic convergence of sequence of random variables	Understand
	MO2. Apply the concepts of convergence to sequences of random variables	Evaluate
	MO3. Construct counter examples for not satisfying certain convergence implications	Create
Module 5	MO1. Derive expressions for the characteristic function for various distributions	Evaluate
	MO2. Find moments using characteristic function	Evaluate
	MO3. Derive expressions for the probability density function corresponding to a given characteristic function	Evaluate
	MO4. Articulate the various theorems associated with the characteristic function and identify their applications	Apply
	MO5. Explain and exemplify the concepts of infinitely divisible distributions	Understand
Module 6	MO1. State and prove the various laws of large numbers	Understand
	MO2. Apply the laws to sequences of random variables	Apply
	MO3. Articulate the concepts of stable distributions	Understand
	MO4. Explain the concepts of Stable distributions and distribution of class L	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

1. Bhat, B.R. (1985): Modern Probability Theory: An Introductory Text Book, 2nd edition, Wiley Eastern.
2. Gnedenoko, B.V. (1969): The Theory of Probability, Mir Publishers, Moscow.
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SEMESTER : II
COURSE CODE : STA-CC-524
COURSE TITLE : THEORY OF ESTIMATION
CREDITS : 4

COURSE OUTCOMES

After completion of this course the students will be able to

C01	Understand fundamental concepts of statistical estimation and inference
C02	Apply various estimation methods to real-world problems
C03	Analyze the properties and performance of different estimators
C04	Evaluate the efficiency and consistency of estimation procedures
C05	Demonstrate proficiency in Bayesian inference techniques

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy level
Module 1	MO1. Define point estimation and sufficiency	Remember
	MO2. Apply Neyman-Pearson factorization theorem	Understand
	MO3. Identify exponential and Pitman families of distributions	Remember
	MO4. Understand Likelihood equivalence and unbiased estimation	Understand
Module 2	MO1. Explain UMVUE estimators and their characterizations	Understand
	MO2. Apply Rao-Blackwell and Lehmann-Scheffe theorems	Understand
	MO3. Find UMVUE using different methods	Understand
	MO4. Estimate parametric functions from standard distributions using UMVUE	Analyze
Module 3	MO1. Define Fisher information measure and its properties	Remember
	MO2. Apply Cramer-Rao inequality and Chapman-Robbins bound	Understand
	MO3. Understand Bhattacharya bounds, efficiency, and consistency	Understand
	MO4. Determine lower bounds on variance of unbiased estimates	Analyze
Module 4	MO1. Apply method of moments and maximum likelihood estimators	Understand
	MO2. Analyze properties of maximum likelihood estimators	Analyze
	MO3. Understand minimum chi-square and least square estimation	Understand
	MO4. Apply estimation methods to real-world scenarios	Apply
Module 5	MO1. Identify location and scale families of distributions	Remember
	MO2. Apply location and scale invariant estimators	Understand
	MO3. Understand Pitman estimators for location and scale parameters	Understand
	MO4. Implement BLUE for location and scale distributions	Apply

Module 6	MO1. Describe basic elements of Bayesian inference	Remember
	MO2. Analyze loss functions and Bayes risk	Understand
	MO3. Understand prior and posterior distributions	Understand
	MO4. Apply Bayes theorem for parameter estimation	Apply

COURSE CONTENT

MODULE I: Point Estimation and Sufficiency: 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: 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 and Cramer-Rao Inequality: 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 Estimation: 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: Bayesian Inference: Basic elements of Bayesian Inference, Loss function, Bayes risk, Prior distribution, Bayes Theorem, Posterior distributions, Bayes estimation of parameters of standard distributions.

REFERENCES

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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,
CO7	Obtain the stationary distribution of a Markov chain
CO8	Describe random walks & gambler's ruin problem.
CO9	Explain and exemplify continuous time Markov chain, Poisson process, pure birth process, birth and death processes, compound Poisson process, Markov Process with discrete states.
CO10	Distinguish between strict and weak (covariance or wide sense) stationarity,
CO11	Explain and exemplify renewal processes, renewal equation.
CO12	Describe and apply renewal theorem.
CO13	Describe Branching processes, offspring distribution, extinction probabilities.

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Articulate and exemplify the concepts of Stochastic processes, time space and state space.	Understand
	MO2. Construction of examples of Stochastic processes	Create
	MO3. Explain the concepts of particular types of stochastic processes like process with stationary independent increments, Markov process, martingales, Wiener process, Gaussian process etc.	Apply
Module 2	MO1. Articulate concepts of Markov chains, transition probability matrix, n-step transition probabilities	Understand
	MO2. Calculate n-step transition probabilities	Evaluation
	MO3. Describe and exemplify classification of states in a Markov Chain	Understand
	MO4. Calculate the periodicity of a Markov Chain	Evaluation
	MO5. Explain the concepts of recurrence, ergodic chains	Understand

Module 3	MO1. Explain and exemplify concepts of limiting behaviour of n- step transition probabilities.	Understand
	MO2. Describe stationary distributions and solve problems	Apply
	MO3. Describe various types of random walks	Understand
	MO4. Explain a gambler's ruin problem	Understand
	MO5. Derivation of the probability of ruin of a gambler's ruin problem	Evaluation
Module 4	MO1. Describe and exemplify: Continuous time Markov chains, Poisson process, pure birth process, birth and death processes.	Understand
	MO2. Derive of steady state probabilities/differential difference equations in case of Poisson process, pure birth process, birth and death processes.	Evaluation
	MO3. Describe and exemplify: Compound Poisson process	Understand
	MO4 Derive properties of Poisson process and Compound Poisson process	Evaluation
	MO5. Explain the concept of Markov Process with discrete states.	Understand
	MO6. Illustrate these processes with examples	Apply
Module 5	MO1. Distinguish between strict and weak (covariance or wide sense) stationarity	Analyse
	MO2. Describe and exemplify: renewal processes, renewal equation.	Understand
	MO3. Explain the statement and applications of renewal theorem	Apply
	MO4. Solve problems based on the applications of renewal theorem	Apply
Module 6	MO1. Describe and exemplify Galton-Watson branching processes	Understand
	MO2. Explain concepts of offspring distribution and its implications	Apply
	MO3. Interpret the concept of extinction probabilities	Apply
	MO4. Compute the probability extinction in case of a particular offspring distribution	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

1. Bartlett, M.S. (1955): An Introduction to Stochastic Processes (with special reference to application and methods), Cambridge.
2. Bhat, U.N. and Miller, G.K. (2002): Elements of Applied Stochastic Processes. 3rd Edn., John Wiley, New York.
3. Feller, W. (1968): Introduction to Probability Theory and its Applications, Vols. I & II, John Wiley, New York.
4. Karlin, S. (1972): A First Course in Stochastic Processes, Academic Press, New York.
5. Parzen, E. (1962): Stochastic Processes, Holden-Day Inc, San Francisco.
6. 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 : TIME SERIES ANALYSIS
CREDITS : 4

COURSE OUTCOMES

After completion of this course the students will be able to

C01	Analyse exploratory time series analysis using time series data
C02	Choose an appropriate model for time series data using the concept of linear time series models
C03	Predict the time series data using different stationary time series data
C04	Describe estimation methods for time series
C05	Forecasting using different forms of the ARIMA models
C06	MMSE Forecasting using ARMA and ARIMA models

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy level
Module 1	MO1. Analyse exploratory time series analysis using time series data	Analyse
	MO2. Stationary time series and autocorrelation functions	Understand
Module 2	MO1. Smoothing methods for time series	Analyse
	MO2. Forecasting based on smoothing	Apply
Module 3	MO1. Linear stationary processes	Analyse
	MO2. Analyse time series data using different stationary time series data	Analyse
Module 4	MO1. Estimation using Yule - Walker methods	Apply
	MO2. Maximum likelihood and least squares estimation for ARMA Processes	Analyse
Module 5	MO1. Linear non-stationary models	Analyse
	MO2. Forecasting using ARMA and ARIMA models	Analyse
	MO3. MMSE forecasts using different forms of the ARIMA models	Analyse
Module 6	MO1. Spectral analysis of stationary process	Understand
	MO2. Correlogram and periodogram analysis	Analyse
	MO3. Non-linear time Series models	Understand

COURSE CONTENT

MODULE I: Time series as a discrete parameter stochastic process, Classical regression in time series context. Characteristics of time series, exploratory time series analysis, test for trend and seasonality. Stationary time series, Autocorrelation (ACF) and cross correlations, partial auto correlation function, Estimation of autocorrelations.

MODULE II: Holt-winter additive and multiplicative models. Smoothing methods for time series: Adaptive smoothing, Kalman smoother, Moving average smoothing, Single exponential smoothing, Double exponential smoothing, Holt-winter smoothing. Forecasting based on smoothing.

MODULE III: Detailed study of the stationary process: Autoregressive, Moving Average, and Autoregressive Moving Average Models. Choice of AR MA periods. Wold representation of linear stationary processes.

MODULE IV: Estimation using Yule - Walker methods for AR, MA and ARMA Processes. Maximum likelihood and least squares estimation for ARMA Processes.

MODULE V: Linear non-stationary models: Autoregressive Integrated Moving Average (ARIMA) models, Integrated moving average (IMA) models. Forecasting using ARMA and ARIMA models. MMSE forecasts using different forms of the ARIMA models.

MODULE VI: Spectral analysis of weakly stationary process. Spectral analysis: Time series in frequency domain, spectral density and discrete Fourier transforms, estimation of spectral density. Correlogram and periodogram analysis. Seasonal ARIMA and GARIMA models. Introduction to non-linear time Series: ARCH and GARCH models. Auto Regressive Distributed Lag (ARDL) time series model.

REFERENCES

1. Box, G.E.P., Jenkins G.M. and Reinsel, G.C. (2007) Time Series Analysis: Forecasting and Control, Pearson Education.
2. Brockwell, P J. and David R. A. (2002). Introduction to Time Series and Forecasting, 2^{nd} edition, Springer.
3. Draper, N. R. and Smith H. (1998). Applied Regression Analysis, 3^{rd} edition. John Wiley
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SEMESTER : III
COURSE CODE : STA-CC-533
COURSE TITLE : TESTING OF HYPOTHESES
CREDITS : 4

COURSE OUTCOMES

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

CO1	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	Derive likelihood ratio test for testing the hypothesis for normal populations
CO7	Obtain sequential probability ratio test for testing the hypothesis.
CO8	Construct confidence interval for parameters
CO9	Construct UMA and UMAU confidence sets
CO10	Perform non-parametric test for a given data
CO11	Formulate hypothesis for a given problem

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1: Identify simple and composite hypothesis	Understand
	MO2: Find critical region, size and power of the test	Evaluate
	MO3: Distinguish between random and non-randomized test	Apply
Module 2	MO1: Apply Neyman-Pearson lemma to find most powerful test	Apply
	MO2: Check the unbiasedness of a test	Apply
	MO3: Find UMP and UMPU test	Apply
Module 3	MO1: Apply likelihood ratio test principle for testing the mean for a normal population.	Apply
	MO2: Apply likelihood ratio test principle for testing the equality of means for two normal population	Apply
	MO3: Test the variance of normal population.	Apply
	MO4: Test the equality of means of two normal populations	Apply
Module 4	MO1: Derive SPRT for test the parameters of normal distribution, binomial and Poisson distributions	Apply
	MO2: Find OC function and Average sample Number of a SPRT	Evaluate
Module 5	MO1: Construct shortest level confidence interval for parameters	Evaluate
	MO2: Construct confidence interval using pivot	Evaluate
	MO3: Use UMP and UMPU test to construct UMA and UMAU confidence sets	Apply
Module 6	MO1: Perform one sample and two sample non-parametric test	Apply
	MO2: Perform Kruskal-Wallis one-way test and Friedman two-way test	Apply

COURSE CONTENT

MODULE I: Basics of Testing of hypothesis, simple hypotheses and composite hypotheses, critical regions and test functions, randomized and nonrandomized tests, Neyman-Pearson lemma and its applications, most powerful tests, uniformly most powerful (UMP) tests.

MODULE II: Unbiasedness, uniformly most powerful unbiased (UMPU) tests, similar test, test with Neyman structure. locally most powerful (LMP) tests, locally most powerful unbiased (LMPU) tests.

MODULE III: Likelihood ratio tests, asymptotic properties, tests concerning mean and variance of normal distribution (one sample and two samples), test concerning means of k normal populations.

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

MODULE V: Confidence sets, shortest confidence intervals, construction of confidence interval using pivots, UMA confidence sets, UMAU confidence sets, relation to tests of hypotheses.

MODULE VI: Nonparametric tests- Test based on Mann-Whiteny U statistics, 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.

REFERENCES

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2. Kendall, M.C, and Stuart. A, (1967): The Advanced Theory of Statistics, Vol 2, IV Edn., Mc Millan, New York.
3. Lehmann, E. L. (1986): Testing of Statistical Hypothesis, John Wiley & Sons.
4. Wald, A. (1977): Sequential Analysis, Dover Publications Inc., New York.
5. Wetherill, G. B. (1966): Sequential Methods in Statistics, Methuen & Co. Ltd. New Delhi.
6. Siegel, S. and Castellan Jr. N. J. (1988): Non-parametric Statistics for the Behavioral Sciences. McGraw Hill, New York.
7. Randles, R.H. and Wolfe, D.A. (1979): Introduction to the Theory of Nonparametric statistics, Wiley New York.
8. Rohatgi, V.K. (1976): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd, New York.

SEMESTER : III
COURSE CODE : STA-DE-534(i)
COURSE TITLE : APPLIED REGRESSION ANALYSIS
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 Goldfeld 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

	On completion of each module, students should be able to:	Taxonomy level
Module 1	MO1. Explain simple linear regression model	Understand
	MO2. Describe least square estimators	Remember
	MO3. Articulate to inference regarding regression parameters	Apply
	MO4. Explain ANOVA	Analyse
Module 2	MO1. Explain multiple linear regression models	Analyse
	MO2. Explain inference regarding multiple regression parameters	Understand
	MO3. Explain Polynomial Regression models	Understand
Module 3	MO1. Establish the scope of econometrics	Apply
	MO2. Explain general linear regression model	Understand
	MO3. Explain multicollinearity	Understand
	MO4. State and prove Farrar-Glauber test for multicollinearity	Remember
Module 4	MO1. Generalized least squares method of estimation	Analyse
	MO2. Explain Heteroscedasticity	Understand
	MO3. Explain test for homogeneity of variances	Apply
Module 5	MO1. Explain auto-correlation	Remember

	MO2. Establish Durbin-Watson test	Apply
	MO3. Establish Von-Neumann test	Apply
	MO4. Instrumental variable estimation	Understand
Module 6	MO1. Explain estimation in simultaneous equation model	Understand
	MO2. Establish 2 SLS estimation and 3 SLS estimation	Apply
	MO3. Discuss identification problems	Understand

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, 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: Goldfeld and Quandt test, Glesjer test.

MODULE V: 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 VI: 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

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

SEMESTER : IV
COURSE CODE : STA-DE-534(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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explains the utility theory and insurance.	Understand
	MO2. Explain survival function and application.	Understand
	M30. Examine the properties of force of mortality.	Apply
	MO4. Define Life tables and its relation with survival function, examples.	Remember
Module 2	MO1.Explain Multiple life functions and its properties.	Understand
	MO2. Articulate the insurance and annuity benefits through multiple life functions evaluation for special mortality laws.	Analysis
	MO3. Explains the Multiple decrement tables.	Understand
	MO4. Describe net single premiums and their numerical evaluations.	Remember
Module 3	MO1. Define Distribution of aggregate claims.	Understand
	MO2. Derive the compound Poisson distribution and explain its applications.	Remember
	MO3. Explain Principles of compound interest and its attributes.	Understand
Module 4	MO1. Explain the Life insurance and its types.	Understand
	MO2. Describe Insurance payable at the moment of death and at the end of the year of death-level benefit insurance	Analyse
	MO3. Explain the Life annuities and its types.	Understand
Module 5	MO1. Explain Net premiums and its importance	Understand
	MO2. Distinguish between Continuous and discrete premiums	Analyse
	MO3. Accumulation type benefits.	Apply

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

1. Beard, R.E., Penlikainen, T. and Pesonnen, E (1984): Risk Theory: The Stochastic Basis of Insurance, 3rd Edition, Chapman and Hall, Londan.
2. 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.
3. Neill, A. (1977): Life Contingencies, Heineman.

SEMESTER : **IV**
COURSE CODE : **STA-DE-534(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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Distinguish various type of survival distributions and their survival time.	Understand
	MO2. Familiar with different test procedures and comparison of two survival distribution.	Analyse
Module 2	MO1. Explain and exemplify the concept of censoring methods.	Understand
	MO2. Evaluate the biological examples with different type of censoring.	Evaluate
Module 3	MO1. Articulate the concept of risk theory.	Apply
	MO2. Explain indices for measurement of probability of death under competing risks and inter-relation.	Understand
	MO3. Evaluate various methods of estimation under competing risk theory.	Analyse
	MO4. Distinguish independent and dependent risks.	Understand
Module 4	MO1. Explain basic biological concepts in genetics.	Understand
	MO2. Describe Mendel's law.	Evaluate
	MO3. Explain mutation and genetic drift.	Understand
	MO4. Discuss and estimate linkage in heredity.	Evaluate
Module 5	MO1. Explain different Phases of clinical trials.	Understand
	MO2. Describe designs for comparative trials.	Understand
	MO3. Express sample size in a fixed sample design.	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

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

SEMESTER : IV
COURSE CODE : STA-CC-541
COURSE TITLE : PRACTICAL
CREDITS : 4

COURSE OUTCOMES

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

CO1	Evaluate the trend and seasonal fluctuations of a real-life time series data using R programming language
CO2	Interpret different multivariate techniques
CO3	Classify the different control charts for industrial data set using R programming language
CO4	Summarize different design of experiments for a statistical experimental data using R programming language
CO5	Recognize different nonparametric tests such as ANOVA, RBD etc. For statistical experimental data using R programming language.

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. 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.	Apply
	MO2. Illustrate the concepts of correlation and Regression	Apply
Module 2	MO1. 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	Evaluate
	MO2. 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	Create
	MO1. Perform tests of hypothesis using multivariate data such as Equality of means of two multivariate normal vectors	Apply
	MO2.Analyze the multivariate data using the multivariate techniques such as Canonical correlation, Principal component analysis, Factor analysis, Cluster analysis.	Analyze
Module 3	MO1. 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 4	MO1. Illustrate different control charts such as Shewart control charts for variables- X, R, S charts, Attribute control charts - np, p, c and u charts using the R software.	Analyze

	MO1. Formulate different experimental techniques such as LSD, ANCOVA, Factorial experiments. Missing and Mixed-up plot in RBD using the R software	Create

COURSE CONTENT

MODULE I: Descriptive Statistics: Compare means- one sample t- test, two sample test, independent sample t test; chi-square test; Correlation; Regression-simple and multiple. Fitting of distributions.

MODULE II: 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 III: Equality of means of two multivariate normal vectors; Canonical correlation, Principal component analysis, Factor analysis, Cluster analysis. Mann-Whitney U-test, Kruskal-Wallis test.

MODULE IV: Control charts - Shewart control charts for variables- X, R, S charts, Attribute control charts - np, p, c and u charts. CRD, RBD, LSD, Factorial experiments.

SEMESTER : **IV**
COURSE CODE : **STA-DE-542(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	CUSUM charts and EWMA mean charts
CO5	Define reliability including the different types and how they assessed
CO6	Ensure the validity and precision of statistical analysis
CO7	Explains reliability in discrete set up

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy level
Module 1	MO1. Explain statistical process control	Understand
	MO2. Describe various control charts	Analyse
Module 2	MO1. Describe different sampling inspection techniques	Evaluate
	MO2. Explains six-sigma concepts	Analyse
Module 3	MO1. Distinguish chain sampling and continuous sampling	Remember
	MO2. CUSUM charts and EWMA mean charts	Understand
Module 4	MO1. Explain basic concepts of reliability	Apply
	MO2. Describe reliability of a coherent system	Analyse
	MO3. Describe several measures of reliability	Understand
	MO4. Calculate measures of reliability based on several distributions	Apply
Module 5	MO1. Explain reliability in discrete set up	Understand
	MO2. Derive expression of the relation connecting various measures of reliability	Evaluate
Module 6	MO1. Explain inference in reliability models	Understand
	MO2. Describe estimation of parameters based on censored sampling	Apply
	MO3. Solve problems related to estimation of parameters based on censored sampling	Apply

COURSE CONTENT

MODULE I: Quality and Quality assurance, Methods of Quality assurance, Introduction to TQM. Statistical process control, Theory of control charts - Shewart control charts for variables: $\bar{X}$, R, σ charts, Attribute control charts - np, p, c and u charts - OC, ARL & process capability of control charts. Acceptance sampling for attributes and variables.

MODULE II: Sampling inspection techniques: Single, double and multistage sampling plans and their properties. Sequential sampling plans. Taguchi method, Experimental design in Taguchi Methods, ISO standardization, ISO 9001, six sigma concepts.

MODULE III: Chain sampling, Continuous sampling plan. Process capability studies, CUSUM charts, EWMA mean charts, Statistical process control, Modelling and quality programming, Economic design of control charts.

MODULE IV: 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 V: Reliability concepts in discrete set up, Notions of ageing - IFR, IFRA, DFR, DFRA, NBU, NBUE, NWU, NWUE, IMRL, DMRL, HNBUE, HNWUE and their mutual implications. TTT transforms and characterization of ageing classes.

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. Reliability estimation using MLE: exponential, Weibull and gamma distributions. Bayesian reliability estimation of exponential and Weibull models.

REFERENCES

1. Barlow, R.E. and Proschan, F. (1985). Statistical Theory of Reliability and Life Testing, Holt, Rinehart and Winston.
2. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman Hall.
3. Duncan, A. J. (1959). Quality Control and Industrial Statistics (5th edition), Irwin, Homewood I.
4. Galambos, J. and Kotz, S. (1978). Characterizations of Probability Distributions.: A Unified Approach with an Emphasis on Exponential and Related Models, Springer-Verlag Berlin and Heidelberg GmbH & Co.
5. Klefjo, B. (1982). The HNBUE and HNWUE Classes of Life distributions, Naval Research Logistic Quarterly, 29, 331-344.
6. Lawless, J. F. (2003). Statistical Models and Methods for Lifetime Data, John Wiley.
7. Montgomery, D.C. (2005). Introduction to Statistical Quality Control, 5th edition, John Wiley.
8. Nelson, W. (1982). Applied life data analysis, Wiley.
9. Sinha, S. K. (1986). Reliability and Life Testing, Wiley.

SEMESTER : IV
COURSE CODE : STA-DE-542(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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain and exemplify the concept of random vectors and infinite dimensional random variables.	Understand
	MO2. State and explain consistency theorem.	Remember
	MO3. State and prove Kolmogorov 0-1 law.	Remember
Module 2	MO1. Explain convolution semigroup.	Understand
	MO2. Describe the representation of the infinitesimal generators.	Evaluate
Module 3	MO1. Describe divisible distribution and elementary properties.	Apply
	MO2. Explain canonical representations.	Understand
	MO3. Describe convolution semigroups and infinitely divisible distribution.	Analyse
Module 4	MO1. State and explain general central limit theorem.	Remember
	MO2. Apply central limit theorem and solve problems related to it.	Apply
Module 5	MO1. Explains distribution of class L.	Understand
	MO2. Distinguish extreme value distributions and stable distributions.	Evaluate
	MO3. Establish domain of attraction.	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

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

SEMESTER : IV
COURSE CODE : STA-DE-542(iii)
COURSE TITLE : DATA MINING AND THEIR APPLICATIONS
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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain classification methods for data	Understand
	MO2. Establish decision trees	Analyse
Module 2	MO1. Distinguish clustering from statistical and data mining	Understand
	MO2. Explain vector quantization	Analyse
Module 3	MO1. Explain dimension reduction	Apply
	MO2. Analyze unsupervised learning from univariate and multivariate data	Analyse
Module 4	MO1. Explain supervised learning from moderate to high dimensional input spaces	Understand
	MO2. Analyze regression trees	Evaluate
Module 5	MO1. Explain simple relation data bases	Understand
	MO2. Analyze online analytical data processing	Evaluate
	MO3. Establish the applications to electronic commerce	Apply

COURSE CONTENT

MODULE I: Data mining: History, Definitions, Data Mining Functionalities, Classification of Data mining System, Major Issues in Data mining, Data warehouse and OLAP Technology, Multidimensional Data Model, Data warehouse Architecture, Data Warehouse Implementation.

MODULE II: Data Preprocessing, Data Cleaning, Data Integration and Transformation, Data Reduction, Discretization and concept of Hierarchy Generation, Concept Description characterization and comparison. Association Rule Mining, Mining Single Dimensional-Multilevel Association Rules, mining to correlation analysis, classification and prediction.

MODULE III: Overview on outliers, nature of Outliers, Outliers in Univariate Data, Outliers in Multivariate Data, Cluster Analysis, Cluster Vs Classification, impact of Outliers on clustering, clustering problems, Clustering Approaches.

MODULE IV: Data-outliers in regression analysis and Time series, Regression and collinearity: Tools for handling multi-collinearity, methods based on singular value decomposition, Robust Regression, ridge regression. Properties of ridge estimator. Additive outlier, Multiplicative outlier and innovational outlier.

MODULE V: Stationary time Series, Auto correlation and Partial auto correlation function, Correlogram analysis, Estimation of ARIMA model parameters, forecasting with Box - Jenkins model, Residual analysis and diagnostic checking.

REFERENCES

1. Box, G.E.P., Jenkins, G.M. and Reinsel, G.C (2004). Time Series Analysis- Forecasting and Control, Pearson Education, Singapore.
2. Daniel T. Larose, (2006): Data Mining: Methods and Models, Wiley-Inter science, New Jersey.
3. Draper, N.R, and H. Smith, Applied regression analysis, 2nd Ed., John Wiley and sons, New York.
4. Hawkins, D.M, (1980): Identification of Outliers, Chapman and Hall, London.
5. Jiawei Han, Micheline Kamber, (2006): Data Mining: Concepts and Techniques, Morgan Kaufmann Publishers, second edition, San Francisco.
6. Krzysztof J. Cios, Wiltold Pedrycz, Roman W. Swiniarski, Lukasz A. Kurgan, (2007): Data Mining: A Knowledge Discovery Approach, Springer Science Business Media, New York.
7. Montgomery, D.C. and Johnson, L.A. (1977) Forecasting and Time Series Analysis, McGraw Hill, New York.
8. Paolo Giudici, (2005): Applied Data Mining: Statistical Methods for Business and Industry, John Wiley & Sons Ltd, England.
9. Peter J. Rousseeuw and Annick M. Lorey, (1987): Robust Regression and Outlier Detection, John Wiley & Sons, United States.
10. Vic Barnett and Toby Lewis, (1978): Outliers in Statistical Data, John Wiley & sons.

SEMESTER : **IV**
COURSE CODE : **STA-DE-543(i)**
COURSE TITLE : **OPERATIONS RESEARCH**
CREDITS : **4**

COURSE OUTCOMES

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

CO1	Describe Simplex method to solve the linear programming problem.
CO2	Explain the steps for 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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain the concepts of linear programming problem.	Understand
	MO2. Solve the linear programming problem by using Simplex method.	Apply
	MO3. Computational steps of Big M Method	Remember
Module 2	MO1. Write the dual of the given linear programming problem.	Evaluate
	MO2. Find the initial basic feasible solution to the given Transportation problem.	Evaluate
	MO3. To determine the optimum assignment problem.	Remember
Module 3	MO1. To be familiar the concept of general linear programming problem	Understand
	MO2. State and prove Kuhn-Tucker necessary and sufficient conditions in a non-linear programming problem.	Remember
	MO3. To solve the non-linear programming problem.	Apply
Module 4	MO1. Explain with examples the probabilistic models in inventory.	Understand
	MO2. Derive an expression for EOQ for Harri's or Wilson model.	Understand

	MO3. Discuss the purchase inventory model with three price breaks.	Remember
Module 5	MO1. State some of the important distributions of arrival interval and service time.	Remember
	MO2. To evaluate expected value of queue length in various models.	Evaluate
	MO3. Obtain the differential difference for M/M/1 queue model.	Understand
Module 6	MO1. Describe the problem of replacement of items whose maintains cost increase with time.	Understand
	MO2. Solve dynamic programming problem by using Linear programming problem.	Apply
	MO3. Describe dynamic programming problem	Remember

COURSE CONTENT

MODULE I: Linear Programming: convex sets and associated theorems, graphical method, definition of linear programming problem, properties of a solution to the linear programming problem, generating extreme-point solutions, simplex computational procedure, artificial variables technique - big M method and two-phase method. Degeneracy in linear programming problem.

MODULE II: Duality problems of linear programming, duality theorems, duality and simplex method. Transportation problems: - general transportation problem, Finding initial basic feasible solution, test for optimality, degeneracy in transportation problem, unbalanced transportation problem. Assignment problem: - mathematical formulation of the problem, the assignment method (Hungarian method).

MODULE III: Non-linear programming problem (NLPP):- general non-linear programming problem, Constrained optimization with equality constraints - necessary conditions for a generalized NLPP, sufficient conditions for a general NLPP with one constraint, sufficient conditions for a general problem with m(<n) constraints, constrained optimization with inequality constraints - Kuhn-Tucker conditions for general NLPP with m(<n) constraints. Quadratic programming problem, convex programming problems.

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

MODULE V: 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 VI: 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. Dynamic programming problem, recursive approach.

REFERENCES

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

SEMESTER : IV
COURSE CODE : STA-DE-543(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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain prior distribution	Understand
	MO2. Interpret Bayes theorem and articulate to find posterior distribution	Analyse
Module 2	MO1. Find conjugate family of prior for a model	Understand
	MO2. Choose appropriate member of conjugate prior for a family	Apply
	MO3. Explain non-informative, improper and invariant priors	Understand
	MO4. Define Jeffrey's invariant prior	Remember
Module 3	MO1. Explain different types of loss function	Apply
	MO2. Evaluate the estimate in terms of posterior risk	Analyse
Module 4	MO1. Explain Bayesian interval estimation	Understand
	MO2. Explain highest posterior density regions	Evaluate
	MO3. Interpret confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval	Apply
Module 5	MO1. Explain testing of hypothesis in Bayesian analysis	Understand
	MO2. Distinguish prior and posterior odds	Apply
	MO3. Establish Lindley's Paradox for testing a point hypothesis for normal mean against the two-sided alternative hypothesis	Analyse

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

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

SEMESTER : **IV**
COURSE CODE : **STA-DE-543(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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explains the basic concepts of distribution of single order statistic, joint distribution of two or more order statistics.	Understand
	MO2. Verify the Markov property of Order statistics.	Remember
	M30. Examine the various properties of Order statistics.	Understand
	MO4. Explain the concept of order statistics	Understand
Module 2	MO1. Explain the moments of order statistic and its properties.	Understand
	MO2. Derive the recurrence relations on the single and product moments of order statistics.	Remember
	MO3. Describe Order statistics from symmetric population.	Understand
Module 3	MO1. Examine order statics of various types of discrete and continuous distributions and articulate their properties	Apply
Module 4	MO1. Explain the different estimators used in order statistics	Evaluate
	MO2.Examine prediction of order statistics.	Apply
	MO3. Find the confidence interval using sample quantile.	Understand
Module 5	MO1. Explains the concept of Record value and its application.	Understand
	MO2. Explains the concept of Concomitant Order statistics and application	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

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

SEMESTER : IV
COURSE CODE : STA-CC-544
COURSE TITLE : DISSERTATION/ PROJECT & VIVA
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.
CO3	Create the problems in statistical study involving planning, sampling and applications of the methods they have studied.

SEMESTER : **IV**
COURSE CODE : **STA-GC-501**
COURSE TITLE : **INTRODUCTION TO DATA ANALYTICS WITH R**
CREDITS : **2**

PREREQUISITES

No prior programming or statistics knowledge is required. Basic computer literacy is recommended.

COURSE OUTCOMES

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

CO1	Understand the fundamental concepts of data analytics and its application using R.
CO2	Apply R programming skills to manipulate, visualize, and analyze data.
CO3	Analyze and interpret data using descriptive and inferential statistical methods.
CO4	Communicate insights effectively through data visualization and reporting techniques.

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Define the basic concepts of R programming and its relevance in data analytics.	Remember
	MO2. Apply R programming techniques to import and preprocess data from various file formats.	Apply
	MO3. Evaluate data quality and perform data cleaning operations.	Analyze
	MO4. Demonstrate proficiency in using R for data manipulation tasks.	Apply
Module 2	MO1. Identify the components of data and perform descriptive statistical analysis.	Remember
	MO2. Visualize data using ggplot2 for exploratory purposes.	Apply
	MO3. Interpret relationships between variables through correlation analysis.	Analyze
	MO4. Apply EDA techniques to gain insights into data distributions and patterns.	Apply
Module 3	MO1. Utilize dplyr and tidyr packages for data manipulation and reshaping.	Apply
	MO2. Implement feature engineering techniques to derive meaningful variables.	Apply
	MO3. Assess and handle missing data and outliers effectively.	Analyze
	MO4. Apply data transformation methods to prepare data for analysis.	Apply
Module 4	MO1. Understand the principles of statistical inference and hypothesis testing.	Understand

	MO2. Apply common statistical tests such as t-tests, chi-square tests, and ANOVA.	Apply
	MO3. Interpret p-values and confidence intervals to make informed decisions.	Analyze
	MO4. Apply hypothesis testing techniques to real-world scenarios.	Apply
Module 5	MO1. Customize plots and graphics using ggplot2 for advanced data visualization.	Apply
	MO2. Develop interactive visualizations using Shiny for dynamic exploration.	Apply
	MO3. Create dynamic reports using R Markdown to communicate insights effectively.	Apply
	MO4. Present and communicate data-driven insights to stakeholders.	Apply

COURSE CONTENT

MODULE I: Introduction to R and Data Import: Overview of R and its applications in data analytics, Basics of R programming: data types, operators, and functions, Data import techniques from various file formats (e.g., CSV, Excel), Cleaning and preprocessing data for analysis.

MODULE II: Exploratory Data Analysis (EDA): Understanding the structure of data: variables, observations, and datasets, Descriptive statistics: measures of central tendency and dispersion, Data visualization using ggplot2: histograms, box plots, scatter plots, Exploring relationships between variables: correlation analysis.

MODULE III: Data Wrangling and Transformation: Data manipulation with dplyr: filtering, sorting, and summarizing data, Reshaping data frames using tidyr: gathering and spreading data, Feature engineering: creating new variables and transforming data, Handling missing data and outliers.

MODULE IV: Statistical Analysis and Hypothesis Testing: Introduction to statistical inference: population, sample, and parameter estimation, Common statistical tests: t-tests, chi-square tests, and ANOVA, Understanding p-values and confidence intervals, Practical applications of hypothesis testing in real-world scenarios.

MODULE V: Advanced Data Visualization and Reporting: Customizing plots and graphics with ggplot2, Interactive visualizations using Shiny, Creating dynamic reports with R Markdown, Presenting and communicating insights effectively.

REFERENCES

1. Hadley Wickham and Garrett Grolemund (2017). R for Data Science: Import, Tidy, Transform, Visualize, and Model Data, O'Reilly Media, Inc.

2. Yihui Xie, J. J. Allaire, Garrett Grolemund (2019). R Markdown: The Definitive Guide, CRC Press.
3. Hadley Wickham (2009). ggplot2: Elegant Graphics for Data Analysis, Springer.
4. Gareth James; Daniela Witten; Trevor Hastie and Robert Tibshirani (2017). An Introduction to Statistical Learning: with Applications in R, Springer.
5. Foster Provost and Tom Fawcett (2013). Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking, O'Reilly Media.

SEMESTER : **IV**
COURSE CODE : **STA-GC-502**
COURSE TITLE : **ELEMENTARY STATISTICAL METHODS**
CREDITS : **2**

COURSE OUTCOMES

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

CO1	Calculate the various measures of central tendency and dispersion, correlation coefficient, regression equations etc.
CO2	Fit various regression equations to data sets
CO3	Explain the concepts of statistical surveys, sampling, census and various sampling methods
CO4	Prepare a questionnaire and conduct a sample survey
CO5	Articulate the concepts of random variable and random distributions
CO6	Describe the properties of various standard distributions and sampling distributions
CO7	Conduct tests of significance for population mean(s), variance(s) (one and two samples), F-test, Testing the significance of a correlation coefficient.
CO8	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

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Calculate the Measures of central tendency and dispersion	Apply
	MO2. Find out the coefficient of correlation and regression equations for given data sets	Apply
	MO3. Fit appropriate regression equations to data sets	Create
Module 2	MO1. Articulate concepts of statistical surveys, sampling and census	Understand
	MO2. Distinguish between the three methods of sampling	Analyse
	MO3. Design a sample survey and carry out the survey	Create
Module 3	MO1. Articulate concepts of random variables, their properties and functions of random variables	Understand
	MO2. Describe and distinguish between the various standard distributions and sampling distributions like Binomial, Poisson and Normal, t, F and Chi square	Apply
	MO3. Derive the various functions of distributions like Binomial, Poisson and Normal, t, F and Chi square	Evaluate
	MO4. Solve various problems associated with distributions like Binomial, Poisson and Normal, t, F and Chi square	Evaluate
	MO5. Fit Poisson, binomial and normal distributions to data sets	Apply
Module 4	MO1. 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	Understand
	MO2: 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	Apply

	MO3. 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	Create
Module 5	MO1. 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	Understand
	MO2. 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	Apply
	MO3. 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	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

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

SEMESTER : IV
COURSE CODE : STA-GC-503
COURSE TITLE : ELEMENTS OF PROBABILITY THEORY
CREDITS : 2

COURSE OUTCOMES

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

CO1	Explain probability space
CO2	Evaluate limits of sequence of events
CO3	State and prove Bayes theorem.
CO4	Explain random variables
CO5	Distinguish probability distribution and distribution function
CO6	Explain properties of distribution
CO7	Calculate expectation and moments of various random variables.
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
CO10	Apply the various laws of large numbers to sequences of random variables

MODULE OUTCOMES

	On completion of each module, students should be able to:	Taxonomy
Module 1	MO1. Explain probability space and limits of sequence of random variance	Understand
	MO2. State and prove monotone and continuity properties of probability measure.	Remember
	MO3. Explain addition theorem	Understand
	MO4. State and prove Borel-Cantelli Lemma	Remember
	MO5. Explain conditional probability and Bayes theorem	Apply
Module 2	MO1. Explain random variables	Understand
	MO2. Explain properties of distribution function	Evaluate
	MO3. Describe moments and articulate to problems related to moments	Analyse
	MO4. State Markov and Liaponov inequality	Remember
Module 3	MO1. Explain characteristic function and its properties	Understand
	MO2. Explain inversion theorem on distribution function	Understand
	MO3. Distinguish continuity theorem and Bochner-Khintchine's theorem of characteristic function	Remember
Module 4	MO1. Explain convergence of sequence of random variables	Understand
	MO2. Apply the concepts of convergence to sequence of random distributions	Apply
Module 5	MO1. State and prove various laws of large numbers	Remember
	MO2. Apply various laws to sequence of random variables	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

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