M.Sc. (STATISTICS): ACADEMIC PROGRAM
(2024 Admission Onwards)

Objectives of the Program

The present program is intended to provide a platform for talented students to undergo higher studies in the subject as well as to train them to suit the needs of society. Apart from teaching core Statistics subjects the students can choose inter-disciplinary, intra-disciplinary and skill-based electives depending upon their interests, under the choice-based credit system. The students are also trained to handle real-life problems through practical classes and project work. As a part of the course, the students are also exposed to various statistical software's.

Program Outcomes:

On successful completion of the M. Sc. Statistics program the students will be able to

PSO.1: Understand the role of probability and statistics in solving real-life problems.
PSO.2: Acquire knowledge of modern statistical techniques relevant to today's scientific community.
PSO.3: Convince the need for systematic analysis of data in any scientific experiment.
PSO.4: Provide consultancy on experimental design and field survey.
PSO.5: Handle any statistical packages.
PSO.6: Handle real-life problems using suitable statistical tools in any discipline as well and they will be able to work in any industry which deals with data.
PSO.7: To become a professionally inclined statistics teacher/statistician/data scientist who has sound knowledge of the subject matter and specializes in knowledge discovery through statistical methods.
PSO.8: To understand basic theoretical and applied principles of statistics with adequate preparation to pursue a Doctoral (PhD) degree or enter the job force as an applied statistician.
PSO.9: To communicate key statistical concepts to non-statisticians.
PSO.10: To gain proficiency in using statistical software/utility for data analysis.

Eligibility

(i) Successful completion with a pass of the first six semesters of the Integrated M.Sc program of CUSAT, who have opted for Integrated M.Sc (IMSc) in Statistics.

OR

(ii) A B.Sc Degree with,

a) Mathematics as a main subject or an optional subject

AND

b) Statistics as a main subject or an optional subject with atleast 55% marks for the main and optional subjects taken together.

Duration of the Course : Four Semesters

Examination : Credit and Semester

2024 onwards : 25 (upto 15 from IMSc and all the remaining seats from CAT Rank List)

SEMESTER - I						
Course Code	**Title of Paper**	**Core/ Elective**	**Credits (Total Credits - 19)**	**Continuous Evaluation**	**End Semester Evaluation**	**Total Marks**
24-322-0101	Mathematical Methods for Statistics	C	4	50	50	100
24-322-0102	Probability Theory - I	C	4	50	50	100
24-322-0103	Probability Distributions	C	4	50	50	100
24-322-0104	Sampling Theory& Methods	C	4	50	50	100
	Elective - I	E	3	50	50	100
Elective - I (Choose any one)						
24-322-0105	Data Analytics using R	E	3	50	50	100
24-322-0106	Statistical Techniques in Data Science using R	E	3	50	50	100

SEMESTER - II						
Course Code	**Title of Paper**	**Core/ Elective**	**Credits (Total Credits - 19)**	**Continuous Evaluation**	**End Semester Evaluation**	**Total Marks**
24-322-0201	Statistical Inference I	C	4	50	50	100
24-322-0202	ProbabilityTheory II	C	4	50	50	100
24-322-0203	Stochastic Processes	C	4	50	50	100
24-322-0204	Practical-I & Viva Voce	C	2	50	50 *a	100
	Elective -II	E	3	50	50	100
	Elective-III *b	E	2	-	100	100
Elective - II (Choose any one)						
24-322-0205	Statistics for National Development	E	3	50	50	100
24-322-0206	Reliability Modeling and Analysis	E	3	50	50	100

SEMESTER - III						
Course Code	**Title of Paper**	**Core/ Elective**	**Credits (Total Credits -21)**	**Continuous Evaluation**	**End Semester Evaluation**	**Total Marks**
24-322-0301	Statistical Inference II	C	4	50	50	100
24-322-0302	Multivariate Analysis	C	4	50	50	100
24-322-0303	Applied Regression Analysis	C	4	50	50	100
24-322-0304	Practical-II, Project & Viva Voce	C	3	50	30 *a + 20 *c	100
	Elective -IV	E	3	50	50	100
	Elective-V (Inter-departmental course/MOOC course *b)	E	3	50*b	50*b	100
Elective–IV (Choose any one of the following) Either an inter-departmental course or an online course *b						
24-322-0305	Time Series Analysis	E	3	50	50	100
24-322-0306	Topics in Mathematical Finance	E	3	50	50	100
24-322-0307	Operations Research	E	3	50	50	100

SEMESTER - IV						
Course Code	**Title of Paper**	**Core/ Elective**	**Credits (Total Credits - 21)**	**Continuous Evaluation**	**End Semester Evaluation**	**Total Marks**
24-322-0401	Design and Analysis of Experiments	C	4	50	50	100
24-322-0402	Practical-III & Viva Voce*d	C	4	50	50 *d	100
24-322-0403	Project	C	4	50	50 *e	100
	Elective -VI	E	3	50	50	100
	Elective -VII	E	3	50	50	100
	Elective -VIII	E	3	50	50	100
Electives-VI, VII, VIII (Choose any three)						
24-322-0404	Statistical Quality Assurance	E	3	50	50	100
24-322-0405	Actuarial Statistics	E	3	50	50	100
24-322-0406	Lifetime Data Analysis	E	3	50	50	100

24-322-0407	Applied Multivariate Statistical Analysis	E	3	50	50	100
24-322-0408	Statistical Forecasting	E	3	50	50	100
24-322-0409	Inference for Stochastic Processes	E	3	50	50	100
24-322-0410	Categorical Data Analysis	E	3	50	50	100
24-322-0411	Directional Data Analysis	E	3	50	50	100
24-322-0412	Statistical Decision Theory	E	3	50	50	100
24-322-0413	Theory of Entropy	E	3	50	50	100
24-322-0414	Statistics for Clinical Research	E	3	50	50	100

***a** End semester evaluation based on viva voce.

***b** A MOOC course from SWAYAM/NPTEL/Moodle/Others will be opted for by the students with approval of the Department Council and it will have END SEMESTER EVALUATION ONLY, for 100 marks.

***c** End-semester evaluation based on project.

***d** The VivaVoce examination is to be conducted externally with at least one external examiner.

***e** End-semester evaluation will be done based on the presentation and project report.

DETAILED SYLLABUS

24-322-0101: MATHEMATICAL METHODS FOR STATISTICS

Course Out come (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Demonstrate and understanding of limits and continuity of various functions	Apply
2.	Evaluate the Riemann-Stieltjes integral and verify the conditions for the existence of the integrals	Evaluate
3.	Distinguish between the concepts of sequence and series, and determine limits of sequences and convergence and approximate sums of series	Analysis
4.	Compute the partial and total derivatives and maxima and minima of multivariable function	Apply
5.	Solve systems of line are quations, diagonalize matrices and Characterize quadratic forms	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	1	2								
CO2	2		3				2	2		
CO3			3						2	
CO4			2				3			
CO5	2						2			

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I:
Riemann-Stieltjes Integral - definition, properties and important theorems, Eulers summation formula, integrators of bounded variation, sufficient conditions for existence of Riemann-Stieltjes integrals, Mean value theorems of Riemann-Stieltjes integrals.

Module-II:
Sequences and series of functions: - Pointwise and uniform convergence, properties and theorems; Multivariable Calculus- limit and continuity, total derivative, directional derivatives, differentiation of composite functions, Taylor's Theorem for a multivariable function, inverse and implicit functions, optima of a multivariable function, method of Lagrange multipliers.

Module-III:
Matrices:- Rank of a matrix, elementary transformations of a matrix and properties, inverse of a matrix by elementary transformations, Generalized Inverse Matrices:- Definition and existence, Solving linear equations, Moore-Penrose inverse, Symmetric matrices - properties of generalized inverse; singular value decomposition.

Module-IV:
Quadratic forms - classification and its characteristic properties, canonical forms, gram matrices, Characteristic roots and characteristic vectors of a matrix, nature of characteristic roots of some special types of matrices, algebraic and geometric multiplicity of a characteristic roots, Cayley-Hamilton theorem, Orthogonal and unitary reductions of quadratic forms, Spectral decomposition of a matrix, singular value decomposition.

References:

1. Searle S. R. and Khuri A. I. (2017). Matrix Algebra Useful for Statistics. Wiley Series in Probability and Statistics, Second Edition.
2. Khuri A.T. (1993). Advanced Calculus with Applications in Statistics, John Wiley & Sons, Inc., USA, Chapters - 3 and 7
3. Apostol T.M. (1996). Mathematical Analysis, Narosa Publshing House, New Delhi, Second Edition, Chapters - 6, 7, 9.
4. Shanti Narayan (1991). A text of book of matrices, S. Chand & Company, New Delhi, Chapters - 3, 6, 7, 10, 11.
5. Searle S.R. (1971). Linear models, John Wiley & Sons, Inc., Chapter - 1
6. Gupta S.L. and Gupta N.R. (2003) Principles of Real Analysis, Second edition, Pearson Education (Singapore) Pte. Ltd.
7. Widder D.A. (1996) Advanced Calculus, Second Edition, Prentice Hall, Inc., New Delhi.
8. Nanda S. and Saxena, V.P. (2000) Real Analysis, Allied Publishers Ltd.
9. Graybill F.A. (1969) Introduction to matrices with applications in statistics, Wadsworth Publishing Company, USA.
10. Rao C.R. (2002) Linear statistical inference and its applications, Second edition, Chapter 1b, 1c.

24-322-0102: PROBABILITY THEORY – I

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Identify sigma fields and Compute limits of a sequence of random variables	Apply
2.	Describe properties of Probability Measure and distribution function	Remember
3.	Define Expectation and moments	Understand
4.	Compute Momentine qualities using Expectations	Apply
5.	Concepts of Independence and its use in Multiplication properties, Zero-one laws	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2						2	2		
CO2			2				2	2	3	
CO3							3			
CO4		1					3			
CO5								2		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Random variables: Algebra of sets, Fields, Sigma fields, Inverse function, Measurable functions, Random variables, Induced sigma fields, Limits of random variables.

Module-II

Probability: General measure space, Lebesgue measure, Lebesgue-Stieltjes measure, Counting measure and their simple properties, Discrete probability space, General probability space as normed measure space, Induced probability space, Extension of probability measures. Distribution function of a random variable, Decomposition of distribution functions, Distribution function of random vectors.

Module-III

Integration with respect to measure (Introduction only), Expectation and moments: Definition and properties, Moment generating functions, Moment inequalities: C_r-, Holder, Jenson and basic inequalities, Product spaces and Fubini's theorem (idea and statement only), Independence: Definitions, Multiplication properties, Zero-one laws.

Module-IV

Convergence: Modes of convergence, Convergence in probability, in distribution, in rth mean, almost sure convergence and their inter-relationships, Convergence theorem for expectation such as Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem (some remarks on the corresponding theorems for general integrals with respect to measure).

References:

1. Billingsley P.(2017)Probability and Measure, Third Edition, Wiley, India Pvt. Ltd.
2. Bhat B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern, Chapters 1,2,3, 4,5,6,9.
3. Laha R. G. and Rohatgi V. K. (2020). Probability Theory, John Wiley and Sons, New York.
4. Rohatgi V. K. and Saleh M. (2015). An Introduction to Probability and Statistics, Third Edition, John Wiley and Sons, New Jersey.
5. Feller W.(1966)An Introduction to Probability Theory and Its Applications, Volume II, Wiley Eastern.
6. Rao C.R.(1973) Linear Statistical Inference and Its Applications, Wiley.
7. Rohatgi V.K. and A.K.E. Salah (2001) Introduction to Probability and Statistics, John Wiley and Sons.
8. Basu A.K.(1999) Measure Theory and Probability, Prentice-Hall.

24-322-0103: PROBABILITY DISTRIBUTIONS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Describe and employ various statistical concepts to study the discrete distributions	Apply
2.	Describe and employ various statistical concepts to study the discrete distributions	Apply
3.	Describe properties of bivariate continuous exponential Distributions	Understand
4.	Illustrate characterization properties of the bivariate exponential	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2						2	3		
CO2	3						2	2		
CO3							3	2		
CO4								3		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Discrete Distributions: Modified power series family - properties, moment generating functions, recurrence relations for raw, central and factorial moments, recurrence relation for cumulants, Binomial, Negative binomial, Logarithmic series and Lagrangian distributions and their properties as special cases of the results from modified power series family, hypergeometric distribution and its properties.

Module-II

Continuous distribution: Pearson family – identifications of the different types, Beta, Gamma, Pareto and Normal Special cases of the Pearson family and their properties. Exponential family of distributions, Compound, truncated and mixture distributions.

Module-III

Sampling distributions: Sampling distributions of the mean and variance from normal population, independence of mean and variance, Chi-square, students *t* and *F* distribution and their non-central forms. Order statistics and their distributions, Conditional distribution of order statistics, distribution of sample range.

Module-IV

Bivariate distributions: Multinominal, bivariate normal, bivariate exponential distribution of Gumbel, Marshall and Olkin and Block and Basu, Dirichlet distribution.

References:

1. Rohatgi V.K (1976) An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
2. Arnold B.C, Balakrishnan N and Nagaraja H.N (1992). A first course in order statistics
3. Galambos J and Kotz's (1978):Characterization of Probability distributions, Springer-Verlag.
4. Ord J.K.(1972) Families of frequency distributions Griffin
5. Johnson N.L, Kotz S and Kemp A.W (1992) Univariate discrete distributions, John Wiley.
6. Johnson N.L Kotz S and Balakrishnan N (1991) Continuous univariate distributions I & II, John Wiley.
7. Johnson N.L, Kotz S and Balakrishnan N(1995) Multivariate Distribution, John Wiley.

24-322-0104: SAMPLING THEORY AND METHODS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Apply various sampling procedures like SRS, Stratified, Systematic, Cluster etc., and estimate the population parameters for attributes and variables	Apply
2.	Estimate population ratio, population mean and population total using ratio, difference and regression estimators	Apply
3.	Explain Midzuno-Sen-Lahiri, Murthy's, Des Raj's sampling strategies Evaluate/under varying probability without replacement sampling	Apply
4.	Understand various types of errors in surveys and procedures to rectify them	Understand
5.	Understand quota, network and adaptive samplings; and evaluate estimator under adaptive sampling	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2		2	1				1		
CO2		2	2					1		
CO3			2							
CO4	1		1							
CO5	1		1							

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-1

Basic concepts:- Population, sample, sampling design, interpenetrating subsampling; Simple Random Sampling (SRS):- SRS with replacement, SRS without replacement, confidence interval, estimation of population proportion, determination of sample size, comparison between SRSWR and SRSWOR; Stratified Random Sampling:- estimation of population mean and total, optimum allocation, other types of allocation, comparison with SRS.

Module-II

Estimation of gain due to stratification over SRS, construction of strata, number of strata, Ratio estimator:- Bias and mean square error, estimation of variance, confidence interval, comparison with mean per unit estimator, optimum property of ratio estimator, unbiased ratio type estimator, ratio estimator in stratified random sampling; Difference estimator and Regression estimator:- Difference estimator, regression estimator, comparison of regression estimator with mean per unit and ratio estimator, regression estimator in stratified random sampling.

Module-III

Systematic sampling:- estimation of population mean and variance, comparison of systematic sampling with SRS and stratified random sampling, circular systematic sampling; Cluster sampling:- estimation of population mean, estimation of efficiency by a cluster sample, variance function, determination of optimum cluster size, clusters of varying sizes; Probability proportional to size with replacement sampling:- estimation of population mean and total, selection of a ppswr sample; Varying probability without replacement sampling I:- properties of a sampling design, Horvitz-Thomson estimator.

Module-IV

Varying probability without replacement sampling II:-Midzuno-Sen-Lahiri sampling strategy, Desraj, Murthy's; Mutistage sampling:- estimation population total with SRS sampling at both stages, multiphase sampling (outline only); Errors in surveys:- effect of unit nonresponse in the estimate, procedures for unit nonresponse; quota sampling, network sampling; Adaptive sampling:- introduction and estimators under adaptive sampling

References:

1. Mukhopadhay P (2009) Theory and methods of survey sampling, Second edition, PHIL earning Pvt. Ltd., New Delhi, Relevant sections of Chapters1-16.
2. Sampath S. (2001) Sampling theory and methods, Alpha Science International Ltd., India, Chapter 10.
3. Arnab R. (2017). Survey Sampling Theory and Applications. Netherlands: Elsevier Science.
4. Bansal A. (2017). Survey Sampling. United Kingdom: Alpha Science International, Limited.
5. Cochran W.G.(1999) Sampling Techniques, Third edition, John Wiley & Sons.
6. DesRaj (1976) Sampling Theory, McGraw Hill.
7. Murthy M.N.(1977) Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
8. Singh D. and Chaudhary F.S. (1986) Theory and Analysis of Sample Survey Designs, Wiley Eastern.

24-322-0105: DATA ANALYTICS USING R

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Develop a scientific computing environment using R	Evaluate
2.	Identify the use of R software to meet the given scientific objective	Analyze
3.	Identify the use of various packages in R	Analyze
4.	Write an efficient program using R to perform routine and specialized data manipulation /management and analysis tasks	Execute

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2	3								
CO2		3		3						1
CO3										3
CO4	1					2				3

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Introduction to statistical software R, Using R as a calculating environment, Arithmetic variables, Functions, Vectors, Expressions and assignments, Logical expressions, Manipulating vectors, matrices, importing of files.

Types of data, Scale of measurement, Data objects in R, Graphical summaries of data-Bar chart, Pie chart, Histogram, Box-plot, Stem and leaf plot, Frequency table, Plotting of probability distributions and sampling distributions, P-P plot, Q-Q Plot, Computations of descriptive statistics measures.

Inference from bivariate data-Scatter plot, Correlation and Regression.

Module-II

Basic programming, Branching with if, Looping with for, Looping with while, Vector-based programming, Program flow, Pseudo-code, Basic debugging, Programming with functions, Vectorized functions, Optional arguments and default values, Vector based programming using functions, Recursive programming, Debugging functions, Data frames, Lists, Use of apply group of functions.

Module-III

Simulation, Congruential generators, Seeding, Random Number Generation- Basic principles of Random number generation, Inversion method, Accept-reject method, Random number generation from Binomial, Poisson Uniform, Exponential, Cauchy and Normal, Rejection with exponential envelope, Box-Muller algorithm.

Module-IV

Statistical Inference Problems Using R-Estimation and confidence intervals-Point estimates of normal mean, confidence interval for normal mean with known and unknown standard deviation. Confidence interval for standard deviation. Confidence interval for proportion.

One sample t-test, two sample t-test, paired t-test, test on standard deviation (chi-square test).

References:

1. Jones O., Maillardet. R. and Robinson, A. (2014). Introduction to Scientific Programming and Simulation Using R. Chapman & Hall/CRC, The R Series.
2. Crawley, M, J. (2012). The R Book, 2nd Edition. John Wiley & Sons.
3. Chambers, J. M. (2008). Software for Data Analysis-Programming with R. Springer-Verlag, New York.
4. Jammalamadaka, S. R. (2007). Essential Statistics with python and R. Kendal Hunt publishing

24-322-0106: STATISTICAL TECHNIQUES IN DATA SCIENCE USING R

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Apply R for visualizing both quantitative and qualitative data, including techniques like Q-Q plots	Apply
2.	Will be able to understand and Apply Two Sample Analysis: Matched pairs analysis, independent samples analysis	Understand and Apply
3.	Have a clear understanding of the assumptions, estimation methods, inferences and diagnostics associated with simple linear regression and multiple linear regression with hands on illustrations using R	Understand and Apply
4.	Execute the knowledge and techniques necessary to analyze binary and categorical response variables using the machine learning techniques	Execute

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	2	2				2	1	2	2
CO2	1	1	2				2	1	2	2
CO3	2	2	2				2	2	2	2
CO4	2	2	2				2	2	2	2

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

An Introduction to R. Data Visualisation: Visualization for Quantitative Data, Visualization for Qualitative Data, Q-Q Plots, Two Sample Analysis: Matched Pairs, Independent Samples, Table Analysis, Correlation.

Module-II

Integrate R to study the Simple Linear Regression Model and assumptions of the Simple linear regression model. Least square estimation, Inferences on the parameters, Confidence Intervals for the regression line. Prediction Intervals. Diagnostics, Residual Analysis, Remedial transformations, Outliers and leverage points, Simple regression based on weighted least squares.

Module-III

Integrate R to study Multiple linear regression, Polynomial regression, Cross-validation, Estimation and inference, Use R for Regression Diagnostic of Multiple Linear Regression, Transformations, and Detecting Multicollinearity. Variable selection:

Module-IV

Use R to study models for binary response variables, estimation and diagnosis methods for logistic and Poisson regressions. Over dispersion Prediction and Residual Analysis. Tree-based methods, Gradient Boosting.

References :

1. C.J Neter J. Kutner, W. Wasserman and M.H. Nachtsheim (2005), Applied Linear Statistical Models, 4th edition. McGraw Hill/Irwin.
2. Montgomery D.C., Peck E.A. and Vining, G.G. (2012) Introduction to Regression Analysis, Fifth edition. Wiley.
3. Crawley M.J (2013), The R Book, ISBN 978-0-470-97392-9 (hardback), John Wiley & Sons, Ltd.

SEMESTERII

24-322-0201: STATISTICAL INFERENCE - I

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Summarize the desirable properties of estimator of a parameter or parameters of any given distribution	Evaluate
2.	Relate complete sufficient statistic, Rao-Blackwell theorem and Lehmann-Scheffe theorem	Analyze
3.	Relate Cramer-Rao, Chapmann-Robbin's and Bhattacharya bounds in connection with lower bound for the variance of an unbiased estimator	Analyze
4.	Compute estimator of parameter or parameters of any given distribution using method of moments, method of maximum likelihood and method of minimum variance	Apply
5.	Judge MLE of parameter or parameters of any given distribution possess its invariance and large sample properties	Evaluate
6.	Compare classical inference and Bayesian inference	Analyze
7.	Evaluate Bayes and minimax estimator of parameter or parameters of any given distribution under given prior density and loss function	Evaluate
8.	Illustrate Metropolis-Hasting algorithm, Gibbs sampler and MCMC method	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2									
CO2							2	3		
CO3							3	2		
CO4				3			2	3		
CO5					3		2	2		
CO6	2				2		2			
CO7								3		
CO8								3		

Module-I

Point estimation: Sufficiency and minimal sufficiency, Exponential family of distributions, Pitman family, Factorization criterion, Likelihood equivalence, Unbiased estimation, Completeness, Ancillary statistics and Basu's Theorem, UMVUE estimators and their characterizations, Rao-Blackwell Theorem, Lehmann-Scheffe Theorem, UMVUE estimation of parametric functions from standard distributions.

Module-II

Fisher information measure and its properties, Fisher information matrix, Lower bound to the variance of an unbiased estimates, Cramer-Rao, Chapman-Robbin's and Bhattacharya bounds, BLUE of parametric functions, Efficiency, Consistency, Weak and strong consistency, Marginal and joint consistent estimators, Equivariance, Pitman estimators.

Module-III

Methods of estimation: Methods of moments, Maximum likelihood, Minimum chi square and its modification, Least square estimation, Properties of maximum likelihood estimators, Cramer-Huzurbazar Theorem, Likelihood equation - multiple roots, Iterative methods, E.M Algorithm.

Module-IV

Basic elements of Bayesian Inference, Loss function, Prior distribution, Bayes Theorem, Posterior distributions, Bayes risk, Bayes principle, Bayes estimators, Minimax estimators, Metropolis-Hastings algorithm, Gibbs sampler, MCMC method.

References:

1. E.L.Lehmann (1998) Theory of Point Estimation, John Wiley and Sons.
2. V. K. Rohatgi and A.K.L.Saleh (2015). An Introduction to Probability and Mathematical Statistics, Third Edition, Wiley.
3. B.K.Kale (2005) A First Course in Parametric Inference, Alpha Science International.
4. Robert C.P.and Casella G (2013) Monte Carlo Statistical Methods, Springer Verlag.
5. Rao C.R.(2009) Linear Statistical Inference and its Applications, Second Edition, Wiley.
6. Casella, Gand Berge R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
7. Mukhopadhay P.(1996) Mathematical Statistics, New Central Book Agency Pvt. Ltd.
8. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference, PHI Learning Pvt. Ltd.

24-322-0202: PROBABILITY THEORY–II

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Employ the Inversion formula, Uniqueness theorem	Apply
2.	Illustrate Convergence of distribution function characteristic functions and moments	Apply
3.	Define Convergence of a series of in dependent random variables	Understand
4.	Describe different forms of Central limit theorems	Understand
5.	Define Conditional expectation and conditional probability	Understand
6.	Demonstrate the Randon-Nikodym Theorem and its applications	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1							2	2		
CO2	2					3	1	2		
CO3	2					3	2			
CO4	2					2	3	1		
CO5	3					2				
CO6							2	3		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Characteristic functions**:** Definition and simple properties, Inversion formula, Uniqueness theorem, Characteristic function and moments, Bochner's Theorem (Statement only), Convergence of distribution function: Weak convergence, Convergence of distribution functions and characteristic functions, Convergence of moments.

Module-II

Laws of Large Numbers**:** Convergence of series of independent random variables, Kolmogorov's inequality, Three series theorem, Weak law of large numbers (Kninchine's and Kolmogorov's), Kolmogorov's strong law of large numbers, Glivenko-Cantelli theorem, Kolmogorov's law of iterated logarithms (without proof).

Module-III

Limit Theorems**:** Central limit theorems for i.i.d random variables, Lindberg-Levy and Liaponov's CLT, Lindberg-Feller CLT, Infinitely divisible distributions--definition, elementary properties and examples, Canonical representation (without proof).

Module-IV

Conditioning: Conditional expectation and its properties, Conditional probabilities, Randon-Nikodym Theorem (Statement only) and its applications. Martingales, Submartingales, Martingale convergence theorem, Decomposition of submaritingales.

References:

1. Bhat B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern, Chapters 7,8,10, 11, 12.
2. Laha R.G. and Rohatgi V.K. (2020) Probability Theory, John Wiley and Sons, New York, Relevant sections of Chapters 2,4, 6.:
3. Billingsley P.(2017) Probability and Measure, Third edition, John Wiley, India Pvt. Ltd.
4. Feller W. (1976) An Introduction to Probability Theory and its Applications, Volume II Wiley Eastern.
5. Hoffmann-Jorgensen J.(1994) Probability with a view towards Statistics, Chapman & Hall.
6. Loeve M.(1977) Probability Theory, Volume I, Fourth edition, Springer-Verlag
7. Loeve M.(1978) Probability Theory, Volume II, Fourth edition, Springer-Verlag.
8. Rohatgi V.K. and Saleh A.K.E. (2015) An Introduction to Probability and Statistics, John Wiley & Sons, New York
9. Resnich S.I.(2005). A Probability Path. Birhauser, Springe

24-322-0203: STOCHASTIC PROCESSES

	Course Outcome (CO)	**Cognitivelevel**

After completion of this course the student should be able to:

1.	Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary and ergodicity	Understand
2.	Classify the states of a Markov chain and apply the ergodic theorem for finding limiting distributions on states	Understand
3.	Understand and apply Poisson, birth-death, renewal processes and Brownian motion	Apply
4.	Describe and use the recurrence relation for generation sizes in a Branching Process and determine the probability of ultimate extinction	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2						3	3		
CO2	2						3	3	1	
CO3	3	2				3	2	3		
CO4	2	2				2				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Markov Chains: Definition, Examples and classification, Discrete renewal equation and basic limit theorem, Absorption probabilities, Criteria for recurrence.

Module-II

Continuous time Markov chains, Examples, General pure birth process, Poisson process, Birth and death process, Finite state continuous time Markov chains, Applications to queuing models.

Module-III

Galton-Watson branching processes, generating function, Extinction probabilities, Continuous time branching processes, Extinction probabilities, Branching processes with general variable lifetime.

Module-IV

Renewal equation, Renewal theorem, Applications, Generalizations and variations of renewal processes, Applications of renewal theory, Brownian motion.

References:

1. Karlin .S. and Taylor H.M. (1975) A First Course in Stochastic Processes, Second edition, Academic Press, Relevant sections of Chapters 1, 2,3, 4, 5and 8.
2. Medhi J. (2020). Stochastic Processes, Fifth Edition, New Age International
3. Bhat B.R.(2002).Stochastic Processes, Second edition, New Age Publication.
4. Cinlar E.(2013).Introduction to Stochastic Processes, Dover Publications.
5. V. G. Kulkarni. (2010). Introduction to Modelling and Analysis of Stochastic Systems, Second Edition, CRC Press.
6. S. M. Ross.(2008).Stochastic Processes, Second edition, John Wiley

24-322-0204: PRACTICAL - I & VIVA VOCE

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Apply the different sampling methods for designing and selecting a sample from a population	Apply
2.	Apply the methods of generating random numbers from different probability distributions and its goodness-of-fit using R software	Apply
3.	Formulate and solve problems which involve setting up stochastic models	Evaluate
4.	Understand the notion of parametric models, point and interval estimation of the parameters of those models using real data	Understand
5.	Apply topics related to the Elective in Semester II using real data sets and interpretation of the results	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3		2	3		2				
CO2	2					2	3	2		
CO3	3		2				3			
CO4	2					3	2	2		
CO5	3						3	2		

Practicals based on topics covered in

24-322- 0104 : Sampling Theory and methods; A sample survey to be executed
24-322- 0201 : Statistical Inference I
24-322- 0203 : Stochastic Processes
24-322- XXXX : Elective II

ELECTIVE II

24-322-0205: STATISTICS FOR NATIONAL DEVELOPMENT

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Explain the concept of economic development, growth in per capita income and distributive justice	Understand
2.	Define the indices of development like Human development index etc.	Understand
3.	Estimate national income through income and expenditure approaches	Apply
4.	Measure inequality in incomes, and measure poverty through measures of incidence and intensity combined	Analyze
5.	Define components of Time series Remember Determine the trend, analyze seasonal Fluctuations, construct seasonal indices Measure cyclical movement	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1		1	2			3				
CO2		2	2			1		1	3	
CO3			3			3			3	
CO4	2		2						2	
CO5	2	2	1			3		2		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Demographic methods:- Sources of demographic data - census, register, adhoc survey, hospital records, demographic profiles of Indian census; Measurement of mortality and life tables - crude, death rates, infant mortality rates, death date by cause, standardized death rate; Complete life tables – its main features, mortality rate and probability of dying, use of survival tables; Measurement of fertility - crude birth rate, general fertility rate, total fertility rate, gross reproduction rate, net reproduction rate; Population growth in developing and developed countries; Population projection using Leslie metric; Labour force projection.

Module-II

Economic statistics:- Index number - its definition, price relatives and quantity or volume relatives, link and chain relatives, consumer price index; Demand analysis - static laws of demand and supply, price elasticity of demand, analysis of income and allied size distribution - Pareto distribution, graphical test, fitting of Pareto's law, log normal distribution and its properties, Lorenz curve and estimation of elasticity; Gini coefficient.

Module-III

Economic development, growth in per capita income and distributive justice, indices of development; Human Development Index, Estimation of national income - product approach, income approach and expenditure approach; Measuring inequality in incomes, poverty measurement - measures of incidence and intensity combined; Time Series:-components of time series, determination of trend, analysis of seasonal fluctuations, construction of seasonal indices, measurement of cyclic movement, random component in time series, smoothing methods.

Module-IV

Introduction to Indian and International Statistical System - role, function activities of Central and State Statistical Organizations; Organization of large scale sample surveys; Role of National sample survey organization; General and special data dissemination systems; Principal publications containing such statistics on the topics - population, agriculture industry, trade, price, labour and employment transport and communications, and finance; Educational and Psychological statistics:-Scaling individual test items, scaling of scores on a test, different types of scores and scaling, scaling of ranking and rating in terms of normal curve, Reliability of test scores, Rulon and Kuder Richardson methods, Reliability of a test, validity, comparison between reliability and validity, Intelligence coefficient.

References:

1. Basic Statistics Relating to Indian Economy(CSO), 1990-Current Indian Statistics
2. CoxPR(1957) Demography, Cambridge University Press
3. Croxton F E and Crowder D J(1967) Applied General statistics, Prentice-HallIndia.
4. Guide to current Indian Official Statistics CSO, Govt. of India ,New Delhi
5. Guide to official Statistics(CSO)-1990
6. Kendall M.G. and Stuart A.(1966).The Advanced Theory of Statistics, Charles Griffin
7. Keyfitz N.(1977) Applied Mathematical Demography-Springer Verlag
8. Mukhopadhyay, P Applied Statistics, Books and Allied (P) Ltd
9. Pollard A H, Yusuf F and Pollard G.N.(1998) Demographic Techniques
10. Saluja M.P, Indian Official Statistical Systems, Statistics Publishing Society, Calcutta
11. Sen A.(1997): Poverty and inequality
12. Statistical System in Indian (CSO)1995
13. UNESCO: Principles for Vital Statistics system, SeriesM-12

ELECTIVE II

24-322-0206: RELIABILITY MODELING AND ANALYSIS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand the various concepts and different notions of ageing used in Reliability analysis and their inter relations	Describe
2.	Identify the various aspects like monotonic failure rates, Bath tub and upside down bathtub shaped failure rates and other related measures for various lifetime distributions	Evaluate
3.	Understand and discover the system reliability using the concept of structure functions	Understand
4.	Understand the concepts like positive dependency and various measures of dependence viz-RCSI, LCSD, PF2, WPQD and their inter relations	Evaluate
5.	Estimate the reliability function for complete and censored samples through the maximum likelihood estimation	Evaluate
6.	Estimate the reliability function for complete and censored samples through Uniformly minimum variance unbiased estimation	Evaluate
7.	Estimate the reliability function for complete and censored samples through the Bayesian Estimation	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3						2	3		
CO2	3		2				2	3	2	
CO3			2				1	3	1	
CO4	1		1	2			2	2	1	
CO5	2		2				2	3	1	
CO6	2		2			3	2	3	1	
CO7	2		2			3	2	3	1	
CO8						2				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Structure functions, Coherent Systems, Basic concepts in reliability: Failure rate, mean, variance and percentile residual life, identities connecting them; Notions of ageing - IFR, IFRA, NBU, NBUE, DMRL,HNBUE, NBUC etc and their mutual implications; TTT transforms and characterization of ageing classes.

Module-II

Structure function, Coherent systems, Reliability systems with dependent components:-Parallel and series systems, k out of n systems, ageing properties with dependent and independents components, concepts and measures of dependence in reliability - RCSI, LCSD, WPQD.

Module-III

Non monotonic failure rates and mean residual life functions, Study of lifetime models viz. exponential,Weibull, lognormal, generalized Pareto, gamma with reference to basic concepts and ageing characteristics: Bivariate Exponential distributions, Marshall-Olkin, Bath tub and upside down bath tub failure rate distributions.

Module-IV

Reliability estimation using MLE - exponential, Weibull and gamma distributions based on censored and non censored samples; UMVUE estimation of reliability function; Bayesian reliability estimation of exponential and Weibull models.

References:

1. Lai C.D and Xie M. (2006): Stochastic ageing and dependence in reliability (Relevant topics) Springer.
2. Sinha S K (1986) Reliability and Life Testing, Wiley Eastern.
3. Barlow R.E. and Proschan F. (1975) Statistical Theory of Reliability and Life Testing, Holt, Reinhart and Winston.
4. Marshall A.W. and Olkin I. (2007) Life Distributions, Springer
5. Galambos J and Kotz S. (1978) Characterization of Probability distributions, Springer
6. Lawless J.F.(2003) Statistical Models and Methods for Life Data, Wiley

SEMESTER III

24-322-0301: STATISTICAL INFERENCE – II

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Summarize the testing problem in statistical testing problem	Evaluate
2.	Evaluate MP and UMP tests corresponding to any given testing problem	Evaluate
3.	Relate confidence interval estimation and testing of hypothesis	Analyze
4.	Compute shortest confidence interval for parameter/s of any given distribution using different methods	Apply
5.	Formulate LR test corresponding to any given testing problem	Evaluate
6.	Construct SPRT corresponding to any given testing problem	Evaluate
7.	Distinguish non-parametric confidence interval and boots trap Confidence intervals	Analyze
8.	Examine the non-parametric alternatives for each parametric tests	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2						3			
CO2							3	3		
CO3						2	3	2		
CO4							2	3		
CO5								3		
CO6								3		
CO7	3					2				
CO8	2							3		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Tests of hypotheses, Formulation of problem, Null and alternative hypotheses, Size of a test, Two kinds of errors, Simple and composite hypotheses, Randomized and non-randomized tests, Power of a test, Most powerful test, Neyman-Pearson lemma and its generalization, Monotone likelihood ratio property, UMP tests, Unbiased tests and UMPU tests with examples., Multiple hypothesis testing, False discovery rate.

Module-II

Confidence interval estimation, Relationship between confidence interval estimation and testing of hypothesis, UMA and UMAU confidence intervals, Shortest confidence intervals, Construction of confidence intervals using pivots, Large sample confidence interval based on maximum likelihood estimator, central limit theorem and Chebyshev's inequality, Bayesian credible regions.

Module-III

Likelihood ratio tests and their properties, Testing mean and variance of a normal population, Testing equality of means and variances of two normal populations, Sequential probability ratio tests, Construction of sequential probability ratio tests with examples.

.

Module-IV

Non-parametric inference: Goodness of fit tests- Chi square test and Kolmogorov Smirnov test for one and two sample problems, Sign test, Signed rank test, Wald-Wolfowitz run test, Median test, Man-Whitney U-test, Non-parametric confidence intervals, Bootstrapping confidence intervals, P-P Plot and Q-Q plot, Kendall's tau, Tests for independence and homogeneity.

.

References:

1. Lehmann E.L.(1998) Testing Statistical Hypothesis, John Wiley.
2. Wald A.(2013) Sequential Analysis, Doves
3. Gibbons J.K. (1971) Non-Parametric Statistical Inference, Mc Graw Hill
4. Rohatgi V.K. and Saleh A.K.E. (2011) An Introduction to Probability and Statistics, John Wiley and Sons.
5. Kale B.K. (2005) A First Course in Parametric Inference, Alpha Science International.
6. Rao C.R. (2009) Linear Statistical Inference and its Applications, Second Edition, Wiley.
7. Casella, Gand Berger R.L(2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
8. Rajagopalan M and Dhanavanthan P.(2012). Statistical Inference, PHI Learning Pvt. Ltd.
9. Dixit U.J.(2016).Examples in Parametric Inference with R Springer.

24-322-0302: MULTIVARIATE ANALYSIS

	Course Outcome (CO)	Cognitivelevel
After completion of this course the student should be able to:		
1.	Describe random vectors and their properties	Understand
2.	Discuss the multivariate normal distribution and its properties	Understand
3.	Understand the concept of Wishart distribution, distributions of simple, partial and multiple correlations and T^2 and D^2 statistics	Understand
4.	Identify various classification methods for multivariate data and cluster analysis	Analyze
5.	Explain principal component analysis and factor analysis	Evaluate
6.	Identify canonical variables and quantify canonical correlation	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1		2	2							
CO2			2			2				
CO3			3			2				
CO4						2				
CO5			2			2				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Multivariate data, preliminary analysis, notion of multivariate distributions, multivariate normal distribution, marginal and conditional distributions, characteristic function, estimation of mean vector and covariance matrix. Wishart distribution and its properties, distribution of simple, partial and multiple correlations based on samples from normal population.

Module-II

Hotelling'sT^2 and Mahalanobis D^2 statistics, properties of T^2 and D^2, multivariate Fisher-Behren's problem. Testing independence of sets of variates, testing equality of covariance matrices and means, Sphericity tests, testing the hypothesis that a covariance matrix equal to given matrix, Mean and covariance equal to a given vector and given matrix.

Module-III

Classification problem - standards of good classification, procedures of classification into one of two populations with known probability distributions, classification into one of two known multivariate normal populations, classification into one of several populations. **Clustering of Observations**: Hierarchical clustering for continuous and categorical data - different choices of proximity measures, Agglomerative and Divisive algorithms, K-means clustering optimum choice of the number of clusters

Module-IV

Principal component analysis- definition, properties and ML estimation; canonical variables, canonical correlation. **Factor Analysis**: The orthogonal factor model, Estimation of factor loading, Factor rotation, Estimation of Factor scores, Interpretation of Factor Analysis. Multidimensional Scaling.

References:

1. Anderson T.W.: An Introduction to Multivariate Statistical Analysis, John Wiley
2. Brian Everitt and Torsten Hothorn(2011) An Introduction to Applied Multivariate Analysis with R, Springer.
3. Johnson R. A. and Wichern, D.W.(2001): Applied Multivariate Statistical Analysis, Prentice Hall of India.
4. Rao C. R.: Linear Statistical Inference and its Applications, John Wiley
5. Rencher A. C. (2002): Methods of Multivariate Analysis, 2nd Ed., John Wiley & Sons.

24-322-0303: APPLIED REGRESSION ANALYSIS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Identify a linear and non linear regression problem	Apply
2.	Model a data using an appropriate Regression model	Analyze
3.	Identify and interpret a regression model	Understand
4.	Examine model diagnostics	Analyze
5.	Identify a Nonparametric Regression problem	Analyze
6.	Apply Non Parametric Regression techniques	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1		2			2					
CO2			2		2					
CO3						2		2		
CO4		2					3			
CO5							2			
CO6						2				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Simple Linear Regression Model, Multiple linear regression model, Least squares estimation, Gauss Markov Theorem, Properties of the estimates, Distribution Theory, Maximum likelihood estimation, Hypothesis testing - likelihood ratio test, F-test; Confidence intervals.: Bonferroni-t-intervals, max modulus t intervals, Scheffes's method, Estimation with linear restrictions, Generalised least squares.(12+4+4hrs)

Module-II

Residual analysis, Departures from underlying assumptions, Effect of outliers, Collinearity, Non-constant variance and serial correlation, Departures from normality, Diagnostics and remedies.

Module-III

Polynomial regression in one and several variables, Orthogonal polynomials, Indicator variable Subset selection of explanatory variables, stepwise regression and Mallows Introduction to non-parametric regression.

Module-IV

Introduction to nonlinear regression, Least squares in the nonlinear case and estimation of parameters, Models for binary response variables, estimation and diagnosis methods for logistic and Poisson regressions. Prediction and residual analysis, Generalized Linear Models – estimation and diagnostics.

References:

1. Montgomery D.C., Peck E.A. and Vining G.G.(2001) Introduction to Regression Analysis, Third edition. Wiley.Chapter2, 3,
2. Seber A.F. and Lee A.J.(2003) Linear Regression Analysis, John Wiley, Relevant sections from chapters 3,4, 5,
3. Searle S.R.(1971) Linear models, John Wiley & Sons, Inc.
4. N. Draperand H. Smith (1986) Applied Regression Analysis–John Wiley & Sons.
5. Fox J. (1984) Linear Statistical Models and Related methods, John Wiley, Chapter 5.
6. Christensen R.(2001) Advanced Linear Modeling, Chapter7.
7. B. Abraham and Ledotter J.(1983) Statistical Methods fo-statistics, or Forecasting, John Wiley & Sons

24-322-0304: PRACTICAL - II, PROJECT & VIVA VOCE

Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand various tools using a programming software	Understand
2.	Apply different statistical testing problems using real datasets and interpretation of the results	Analyze
3.	Apply different multivariate techniques using real datasets and interpretation of the results	Analyze
4.	Apply different regression techniques using real data sets and interpretation of the results	Evaluate
5.	Apply topics related to the Elective in the Semester III using real data sets and interpretation of the results	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1					3	3			2	3
CO2	1	2			3	3	2		2	3
CO3					3	3	2		2	3
CO4					3	3	2		2	3
CO5					3	3	2		2	3

Practicals based on topics covered in

24-322-0301; Statistical Inference II
24-322-0302: Multivariate Analysis
24-322-0303: Applied Regression Analysis
24-322-**xxxx**: Elective III

ELECTIVE – IV

24-322-0305: TIME SERIES ANALYSIS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Define time series in time and frequency domain	Remember
2.	Assess the stationarity of time series and its decomposition	Evaluate
3.	Identify suitable ARMA models for the stationary component of the given time series	Analyze
4.	Estimate the parameters of the identified models	Analyze
5.	Discuss the validity of the model by residual analysis	Understand
6.	Prediction by MMSE methods	Evaluate
7.	Analyze Spectral density and periodogram	Analyze
8.	Analyze time series in a state space setup	Analyze
9.	Compute Smooth and filter by Kalmanalgorithm	Apply
10.	Identify a model for the given time series	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2	3			3		1	2		1
CO2	3	2			1			2		
CO3							2	3		
CO4	2	1			3		2			1
CO5	3							2		1
CO6								3		
CO7								2		
CO8								3		
CO9								2		
CO10	2									

Module-I

Characteristics of time series: Time series as a discrete parameter stochastic process, Auto-correlation function (ACF) and cross correlations, Stationary time series, Estimation of autocorrelations. Classical regression in time series context, exploratory data analysis, smoothing methods for time series. Wold representation of linear stationary processes.

Module-II

Linear time series models: Autoregressive (AR), Moving Average (MA), Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models. Forecasting and estimation of ARMA models. Seasonal ARIMA models, Residual analysis and diagnostic checking. ARCH and GARCH models (Basic definition only). Non Gaussian time series (Basic definition only)

Module-III

Spectral analysis: Time series in frequency domain, spectral density, periodogram and discrete Fourier transforms, estimation of spectral density, multiple series and cross spectra, linear filters.

Module-IV

State space models: Filtering, smoothing and forecasting using state space models, Kalman smoother, Maximum likelihood estimation, Missing data modifications.

References:

1. Shumway R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications, Springer.
2. Chatfield C. (2004). The Analysis of Time Series - An Introduction, Sixth edition, Chapman and Hall.
3. Box G. E. P. Jenkins, G. M. and Reinsel G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.
4. Brock well P.J and Davis R.A. (2006). Tim32e Series: Theory and Methods, 2ndedn Springer- Verlag
5. Abraham B. and Ledolter, J.C. (1983), Statistical Methods for Forecasting, Wiles 3. Anderson T.W (1971). Statistical Analysis of Time Series. Wiley.
6. Fuller W.A. (1978). Introduction to Statistical Time Series, Jolin Wiley
7. Kendall M.G. (1978). Time Series, Charler Graffin.
8. Tanaka K. (1996). Time Series Analysis, Wiley Series

24-322-0306: TOPICS IN MATHEMATICAL FINANCE

	Course Outcome (CO)	Cognitivelevel
After completion of this course the student should be able to		
1.	Define the terms: interest rate, options, pay-off, arbitrage, Brownian geometric motion, mean reversion etc.	Remember
2.	Describe and prove arbitrage theorem, Black Scholes theorem	Evaluate
3.	Distinguish call and put options	Understand
4.	Analyze portfolios viautility functions	Analyze
5.	Apply CAPM	Apply
6.	Assess the value at risk	Evaluate
7.	Describe exotics by simulation	Understand
8.	Employ and fit AR models for log prices	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3							2		
CO2								3		
CO3							2	3		
CO4							3	3		
CO5								3		
CO6							3	3		
CO7					3					
CO8	2					3		2		

Module-I

Interest rate and Present value analysis, rate of return, Continuously varying interest rate. Options, Pricing contracts via arbitrage, Arbitrage theorem, single and multi-period binomial model.

Module-II

Geometric Brownian motion, The Black-Scholes formula, Properties of the Black-Scholes option cost, the delta hedging arbitrage strategy, Derivatives, Call options on dividend-paying securities, Pricing American put options.

Module-III

Adding jumps to geometric Brownian motion, Estimating the volatility parameter, Valuing investments by expected utility, The portfolio selection problem, Value at risk and conditional value at risk, The Capital Assets Pricing Model.

Module-IV

Exotic Options, Barrier options, Asean and look back options, Pricing exotic options by simulation, Pricing with nonlinear payoffs, Approximation via multi period binomial models, Crude oil data, Autoregressive moving average models for returns, Mean reversion.

References:

1. Sheldon M. Ross (2003). An Elementary Introduction to Mathematical Finance.
2. Cambridge University Press.
3. A.N. Shiryave (1999). Mathematical Finance, Theory and Practice, World Scientific.
4. David Ruper (2004). Statistics and Finance-An Introduction, Springer International Edition.
5. Fima C.Klebener (1997). Introduction to Mathematical Finance, World Scientific
6. John C.Hull (2008).Options, Futures and other derivatives, Pears on Education India.

24-322-0307: OPERATIONS RESEARCH

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Examine the properties of linear programming problem	Analyze
2.	Solve different types of LPP	Apply
3.	Solve LPP using duality	Apply
4.	Employ transportation and assignment problems	Apply
5.	Solvenon-linear programming problems	Apply
6.	Explain quadratic and convex programming problems	Understand
7.	Examine deterministic and probabilistic inventory models	Analyze
8.	Employ inventory models in real situations	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2		2			1				
CO2	2		2							
CO3	2		2							
CO4	3					1				
CO5	1		1			1				
CO6	1		1			1				
CO7	1		2			1				
CO8			2							

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, two phase method; Revised simplex method.

Module-II

Duality problems of linear programming:-unsymmetric primal-dual problems, symmetric primal-dual problems, Degeneracy and anticycling procedures:- perturbation techniques. Transportation problems:- general transportation problem, Finding initial basic feasible solution, test for optimality, degeneracy in transportation problem, unbalanced transportation problem, maximization 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 inventory models - general inventory model, Static economic-order quantity (EOQ) models - classic EOQ model, EOQ with price breaks, multi-item EOQ with storage limitation, Probabilistic inventory models:- Continuous review models - "probabilitized" EOQ model, probabilistic EOQ model, Single-period models - No setup model (Newsvendor model), setup model (*s*-*S* policy).

References:

1. Gass S.I.(1985) Linear Programming-methods and applications, Fifth edition, McGraw Hill, USA, Chapters 2-7.
2. Kanti Swarup, Gupta,P.K. and ManMohan (2001) Operations Research, Ninth edition, Sultan Chand & Sons, Chapters 3,4, 10, 11 & 24.
3. Taha H.A. (2007) Operations Research- An introduction, Eighth edition, Prentice-Hall of India Ltd., Chapters 11, 14 &15.
4. Ravindran A, Philips D.T and Soleberg J.J.(1997) Operation Research-Principles and Practice, John Wiley & Sons.
5. Sinha S.M.(2006) Mathematical programming theory and methods, Elsevier, a division of Reed Elsevier India Pvt. Ltd., New Delhi.
6. Paneerselvam R.(2008) Operations Research, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi.

SEMESTER IV

24-322-0401: DESIGN AND ANALYSIS OF EXPERIMENTS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand the basic principles and guidelines of Design of experiments	Apply
2.	Design and analyze CRDRBD, LSD and Greaco LSD	Apply
3.	Apply in complete block designs in designing experiments and analyze them	Analyze
4.	Understand and apply the factorial designs and its various versions	Apply
5.	Apply Response surface methodology understanding various aspects involved in it	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2	2	3	3			3	3	3	
CO2	3	3	3	3			3	3	3	
CO3	3	3	3	3			3	3	3	
CO4	3	3	3	3			3	3	3	
CO5	3	3	3	3			3	3	3	

Module-I

Randomization, Replication and local control, One way and two way classifications with equal and unequal number of observations per cell with and without interaction, Fixed effects and Random effects model. Model adequacy checking, CRD, RBD and Latin Square designs, Analysis of co-variance for completely randomized and randomized block designs. Analysis of experiments with missing observations.

Module-II

Incomplete Block Designs: Balanced Incomplete Block designs, Construction of BIB Designs, Analysis with recovery of inter-block information and intra-block information. Partially balanced incomplete block designs, Analysis of partially balanced incomplete block designs with two associate classes, Lattice designs.

Module-III

2^n Factorial experiments. Analysis of 2^n factorial experiments. Total confounding of 2^n designs in 2^P blocks. Partial confounding in 2^P blocks. Fractional factorial designs, Resolution of a design, 3^n factorial designs. Split plot design and strip plot design (outline only).

Module-IV

Response surface designs - orthogonality, rotatability blocking and analysis - Method of Steepest accent, Models, properties and Analysis.

References:

1. Montgomery D.C.(2001)) Design and Analysis of Experiments, John Wiley.
2. Das M N and Giri N.C.(1979) Design and Analysis of Experiments, second edition, Wiley.
3. Hinkleman and Kempthrone,C.(1994) Design and Analysis of Experiments-I, John Wiley.
4. Joshi D.D.(1987) Linear Estimation and Design of Experiments, Wiley Eastern.
5. Chakrabarti M.C.(1964) Design of experiments, ISI, Calcutta

24-322-0402: PRACTICAL – III &VIVA VOCE

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand the various computational techniques using R	Understand
2.	Develop programming skill to meet the given Scientific objective	Analyze
3.	Apply different DoE techniques using real data sets and interpretation of the results	Apply
4.	Apply topics related to the Elective I in the Semester IV using real data sets and interpretation of the results	Apply
5.	Apply topics related to the Elective II in the Semester IV using real data sets and interpretation of the results	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1				2	3	2				3
CO2		2	2		3	2				3
CO3				3	2	3				3
CO4			2		1	3	2			3
CO5			2		3	3	3			3

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Practical based on topics covered in

24-322-0401: Design and Analysis of Experiments.
Elective IV, Elective V, Elective VI

ELECTIVE VI, VII, VIII (Choose any three)

24-322-0404: STATISTICAL QUALITY ASSURANCE

	Course Outcome (CO)	Cognitivelevel
After completion of this course the student should be able to:		
1.	Apply different statistical quality control techniques including various types sampling plans for attributes and measure the performance of these plans	Apply
2.	Explain and design various types of control charts, design control charts and distinguish between them	Apply
3.	Explain acceptance sampling by variables, Sampling Plans for a single and double specification limits with known and unknown variance	Analyze
4.	Sampling plans with double specification limits	Apply
5.	Compare sampling plans by variables and attributes and Continuous sampling plans I, II & III	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	1					2			2	2
CO2	2	1	2			1			2	1
CO3		2	2			1			2	
CO4		2	1				2		2	
CO5			2			2	2		2	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Quality and quality assurance, Methods of quality assurance, Introduction to TQM and ISO 9000 standards, statistical quality control: Acceptance sampling for attributes, Single sampling, Double sampling, Multiple and sequential sampling plans, Measuring the performance of these plans.

Module-II

Control charts, Basic ideas, designing of control charts for the number of non-conformities and fraction non-conformities, mean charts, Median charts, Extreme value charts, R-charts, and S-charts, ARL, Economic design of Shewarts control charts.

Module-III

Acceptance sampling by variables, Sampling plans for a single specification limit with known and unknown variance, Sampling plans with double specification limits, Comparison of sampling plans by variable and attributes, Continuous sampling plans I, II and III.

Module-IV

Process capability studies, Statistical aspect of six sigma philosophy, Lean concepts, Control charts with memory - CUSUM charts, EWMA-mean charts, OC and ARL for control charts, The Taguchi Method: The Taguchi philosophy of Quality, Loss functions, SN ratios, Performance measures, Experimental design in Taguchi Methods: Orthogonal arrays and linear graph, Estimation of effects, Parameter Design.

References:

1. Montgomery R.C.(1985).Introduction to Statistical Quality Control, Fourth Edition, Wiley.
2. Mittag H.J.& amp; Rinne H.(1993) Statistical Methods for Quality Assurance, Chapman & amp; Hall, Chapters 1, 3 and 4,15
3. The ISO 9000 book, Second Edition, Rabbit J T and Bergle P A Quality resources,Chapter-I
4. Schilling E.G.(1982)Acceptance Sampling in Quality Control, Marcel Dekker.
5. Amitava Mitra-Fundamentals of Quality Control and Improvement–Pearson Education Asia 2001 – Chapter 12 (relevant parts)
6. Duncan A.J.(1986) Quality control and Industrial Statistics.
7. Grant E.L. and Leaven Worth R.S.(1980) Statistical Quality Control, Mc Graw Hill.
8. Chin-KneiCho (1987) Quality Programming, John Wiley.

24-322-0405: ACTUARIAL STATISTICS

Course Outcome (CO)	Cognitivelevel
After completion of this course the student should be able to:	
1. Understand the concept of risk and lifetime tables	Understand
2. Evaluate life insurance products, compound interest and discount factor, benefit payable at the moment of death, benefit payable at the end of year of death	Evaluate
3. Understand and evaluate annuities and premiums	Understand and Evaluate
4. Understand concepts related to Reserves - fully continuous reserves, fully discrete reserves; Multiple life contracts - joint life status	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	2	2	2			2	2		2	
CO2	2	2	1			2	2		2	
CO3	2	2	2			2	2		2	
CO4	2	2	2			2	2		2	

Module-I

Insurance business - introduction, insurance companies as business organizations, concept of risk - failure lifetime distributions and life tables, future lifetime random variable, curtate future lifetime, life tables.

Module-II

Actuarial present values or benefit in life insurance products, compound interest and discount factor, benefit payable at the moment of death, benefit payable at the end of year of death – relation between these quantities.

Module-III

Annuities - annuities certain, continuous life annuities, discrete life annuities, life annuities with monthly payments, premiums- Loss at issue random variable, fully continuous premiums, fully discrete premiums.

Module-IV

Reserves - fully continuous reserves, fully discrete reserves; Multiple life contracts - joint life status, last survivor status.

References:

1. Desmukh S. R. (2009). Actuarial Statistics - An Introduction Using R, 3rd Edition. Universities Press (India) Private Ltd., Hyderabad.
2. Promislow, S. D. (2006). Fundamentals of Actuarial Mathematics, John Wiley, Chapters 2-11 and 14.
3. Dickson, C. M. D. (2016). Insurance Risk and Ruin, 2nd Edition. Cambridge University Press, United Kingdom.
4. Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A. And Nesbitt, C. J. (1997). Actuarial Mathematics, 2nd Edition. Society Of Actuaries, Illinois.

24-322-0406: LIFETIME DATA ANALYSIS

	Course Outcome (CO)	Cognitivelevel
After completion of this course the student should be able to:		
1.	Understand the basic concepts and ideas of survival analysis	Understand
2.	Examine the properties and methods for standard survival time distributions	Analyze
3.	Estimate survival functions using parametric and non-parametric methods	Evaluate
4.	Apply and interpret semi-parametric and parametric regression models for survival data	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	2				3	1	2	2	
CO2	2	2				3	1	2	2	
CO3	2	1	2			3	3	2	1	
CO4	1	1	1			3	3	2	1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Basic Quantities and Models - Survival function, Hazard function, Mean residual life function, Common Parametric Models for Survival Data; Censoring and Truncation - Right Censoring, Left or Interval Censoring, Truncation, Likelihood Construction for Censored and Truncated Data, Counting Processes.

Module-II

Nonparametric Estimation of Basic Quantities for Right Censored and Left Censored Data - Estimators of the Survival and Cumulative Hazard Functions for Right Censored Data, Point wise Confidence Intervals for the Survival Function (without derivation), Estimators of the Survival Function for Left-Truncated and Right-Truncated Data; Estimation of the Survival Function for Left, Estimating the Hazard Function, Hypothesis Testing - One-Sample Tests, Tests for Two or More Samples.

Module-III

Semi-parametric Proportional Hazards Regression with Fixed Covariates - Coding Covariates, Partial Likelihoods for Distinct-Event Time Data, Partial Likelihoods when Ties are present, Model Building using the Proportional Hazards Model, Estimation for the Survival Function; Regression Diagnostics - Cox-Snell Residuals for assessing the fit of a Cox Model, Graphical Checks of the Proportional Hazards Assumption, Deviance Residuals.

Module-IV

Inference for Parametric Regression Models - Exponential, Weibull and Log Logistics; Multiple Modes of Failure – Basic Characteristics and Model Specification, Likelihood Function Formulation, Nonparametric Methods.

References:

1. Klein J.P. and Moeschberger M.L.(2003) Survival Analysis-Techniques for censored and truncated data, Second Edition, Springer-Verlag, New York,
2. Lawless J.F (2003) Statistical Models and Methods for Lifetime Data, Second Edition, John Wiley & Sons, Relevant Sections of the Chapters9.
3. Kalbfleisch J.D and Prentice, R.L. (2002) The Statistical Analysis of Failure Time Data, Second Edition, John Wiley &Sons Inc.
4. Hosmer Jr.D.W and Lemeshow S(1999)Applied Survival Analysis-Regression Modelling of Time to Event Data, John Wiley &Sons. Inc.
5. Nelson.W(2003) Applied Life Data Analysis.
6. Miller R.G.(1981) Survival Analysis, John Wiley.
7. Deshpande J.V. and Purohit S. G. (2006). Lifetime Data: Statistical Models and Methods. World Scientific.

24-322-0407: APPLIED MULTIVARIATE STATISTICAL ANALYSIS

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Distinguish multivariate data and its preliminary analysis	Understand
2.	Examine properties of principal component analysis	Analyze
3.	Apply PCA and canonical variates to real data	Apply
4.	Analyze factor model	Understand
5.	Illustrate the factor analysis	Apply
6.	Outline different clustering and similarity techniques	Understand
7.	Apply various clustering and similarity techniques	Apply
8.	Infer multivariate data using MANOVA	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1		2					2			
CO2			2				2			
CO3						2				
CO4						2				
CO5			2							
CO6			2			2				
CO7						2				
CO8			2			2				

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Multivariate Data, Types and preliminary methods of analysis, Principal components Analysis: - population principal components, summarizing sample variation by principal components, graphing the principal components, large sample inference, monitoring quality with principal components; Canonical correlation analysis: - canonical variates and canonical correlations, interpreting the population canonical variables, the sample canonical variates and sample canonical correlations.

Module-II

Factor analysis: - orthogonal factor model; methods of estimation, factor rotation, factor scores, perspectives and a strategy for factor analysis.

Module-III

Cluster analysis: - similarity measures, hierarchical clustering methods, non-hierarchical clustering methods; Distance methods: - multidimensional scaling, correspondence analysis.

Module-IV

Comparison of several multivariate population means (one-way MANOVA), simultaneous confidence intervals for treatment effects, two-way multivariate analysis of variance; profile analysis; Repeated measures designs and growth curves, path analysis.

References:

1. Johnson, R.A. and Wichern, D.W. (2007) Applied Multivariate Statistical Analysis, PHI Learning Private Ltd, New Delhi, Sixth edition, Relevant sections from Chapters 1, 6, 8, 9, 10 & 12.
2. DillonW.R.and Goldstein M (1984) Multivariate Analysis, John Wiley, Relevant sections from Chapter12.
3. Seber G.A.F. (1983) Multivariate Observations, Wiley.
4. Tabachnick B.G. and Fidell L.S.(2018) Using multivariate statistics, Sixth edition, Pearson India Education Services Pvt. Ltd, India.
5. Gnandesikan R., Methods of Statistical Data Analysis of Multivariate Observations, Wiley.
6. Jambu, MandLebeauxM.O., Cluster Analysis and Data Analysis.
7. Lebart, Lmorinean A. and Warwick K.M., Multivariate Descriptive Statistical Analysis, JohnWiley.
8. Davison, Multidimensional Scaling, John Wiley.
9. Morrison D.F., Multivariate Statistical Methods, Mc Graw Hill.
10. Rencher A.C.(1995) Methods of Multivariate Analysis, John Wiley.

24-322-0408: STATISTICAL FORECASTING

	Course Outcome(CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Define various types offorecasts and their performance measures	Remember
2.	Compute forecasts based on regression models	Apply
3.	Compute forecast by simple and double exponential smoothing	Apply
4.	Understand algorithms of Holt-Winters methods for forecasting	Understand
5.	Estimate and forecast seasonal time series	Evaluate
6.	Describe explicit forms of stationary and non-stationary time series models and derive the forecasts	Evaluate
7.	Describe forecast formula for state-space models	Evaluate
8.	Smoothing and filtering by Kalmanfilters	Analyze
9.	Choose a model and construct forecast formula for a given time series	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3						3	2		
CO2	2	3				2		2		2
CO3							3	3		
CO4								3		
CO5							2	2		
CO6	2							3		
CO7							2	2		
CO8								3		
CO9								3		

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Review of linear regression and time series models. Forecasting in constant mean model, Locally constant mean model and simple exponential smoothing. Regression models with time as independent variable, Discounted least squares and general exponential smoothing. Locally constant linear trend model and double exponential smoothing, Prediction intervals.

Module-II

Seasonal time series, Globally constant seasonal models, Locally constant seasonal models, Winters' seasonal forecast procedures (additive and multiplicative), Seasonal adjustment procedures.

Module-III

Forecasts based on stationary ARMA and non-stationary ARIMA models. Transfer function models and forecasting.

Module-IV

State-space models- Filtering, smoothing and forecasting. Kalman filter. Vector ARMA models and Forecasting.

References:

1. Abraham B and Ledolter J (2005) Statistical Methods for Forecasting, John Wiley and Sons, NewYork.
2. Shumway R. HandStoffer, D.S.(2006). Timeseries Analysis and its Applications. Springer.
3. Montgomery D.C., Jennings C.L. and Kulachi M.(2011). Introduction to Time series analysis and Forecasting, Wiley Inter science.
4. Pankratz A. (2009) Forecasting with univariate Box-Jenkins models, John Wiley Sons, NewYork
5. Makridakis S, Wheel wright S.C., Rob J. Hyndman.(2005). Forecasting Methods and Applications, Third Edition, John Wiley and Sons
6. Box,G.E.P. Jenkins, G.M. and Reinsel G.C. (2015).Time Series Analysis: Forecasting and Control, Fourth Edition, Wiley.
7. Brockwell P.J. and Davis R.A. (2013) Introduction to Time Series and Forecasting, second edition, Forth Edition, Springer.

24-322-0409: INFERENCE FOR STOCHASTIC PROCESSES

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Define relevant optimality criteria for inference in stochastic processes	Remember
2.	Choose suitable method of estimation and test procedure for given process	Evaluate
3.	Compute estimates for relevant parametric functions for Markov chains in discrete and continuous time space	Apply
4.	Produce the asymptotic properties of the estimators for such processes	Apply
5.	Compute the estimates and test statistics for continuous time Markov processes such as Poisson processes, birth-death processes, etc.	Apply
6.	Give examples for processes satisfying the regularity conditions under which estimators and test functions behave well	Understand
7.	Identify a suitable stochastic model for the given situation	Analyze

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	1	2				2	2		2	
CO2	1	2				1	2		2	
CO3		1				2			2	
CO4	2						2		1	
CO5		2	1			2	2		1	
CO6	1	1	1			2			2	
CO7	2	2	2			2			1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Brief review of basic principles of methods of statistical inference, Inference for the Galton-Watson process, The Markov branching process, Estimation and prediction in Auto regressive process.

Module-II

Inference in discrete Markov chains: Maximum likelihood estimation, Asymptotic properties of estimators, Asymptotic distribution of serial correlation, Tests of hypothesis tests of independence based on serial correlation Bayesian analysis, Inference for an absorbing chain Inverse likelihood estimation of states, Macro model, grouped Markov chains, Estimation in countable state-space Markov chain.

Module-III

Inference in continuous time Markov chains: Inference in finite Markov chains, queuing models, pure birth and death process, Homogeneous and non-homogeneous Poisson processes, Inference for renewal process in relation to reliability applications.

Module-IV

Large sample theory for discrete parameter stochastic process, Estimation, Consistency, Asymptotic normality, Efficiency, Robustness, Maximum likelihood estimation for some optimal asymptotic tests.

References:

1. Basava, I.V. and Prakasa Rao, B.L.S. (1980) Statistical Inference for Stochastic Processes Academic Press Chapters 1-7.
2. Billingsley,P. (1961) Statistical Inference for Markov Processes, University of Chicago Press.
3. Chung K.L. (1967) Markov Chain with Stationary Transition Probabilities 2nd edition, Springer-Varlag
4. Karr A.R.(1991) Point Processes and Their Statistical Inference, Marcel Dickker
5. Keiding N. (1974) Estimation in the Birth Process, Biometrika,61,71-80.
6. Keiding N. (1975) Maximum Likelihood Estimation in the Birth and Death Process, Annals of Statistics, 3,363-372.
7. Rajarshi M.B. (2013). Statistical Inference for Discrete time Stochastic Processes. Springer.

24-322- 0410 Categorical Data Analysis

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand a categorical data	Understand
2.	Able to perform table analysis	Apply
3.	Analyze categorical data using appropriate statistical models	Analyze
4.	Able to use R software to effectively implement the above	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	3			3	3	3	3	
CO2	3	3	3			3	3	3	3	
CO3	3	3	3			3	3	3	3	
CO4										3

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-1

Introduction to Categorical Data-Categorical Data, Discrete Distributions and Related Inference Problems, Statistical Inference with Categorical Data, Classes of Models for Discrete Data Analysis of Two-way Tables- Analyzing 2 2 Tables, Analyzing *IJ T*ables, Test of Independence for Ordinal Variables, Graphs for Two-way Tables

Module-II

Analysis of Multi-way Tables.- Describing Multi-way Contingency Tables, On Partial and Marginal Tables, Analysis of *K*2x2 Tables, Types of Independence for Three-way Tables, Graphs for Multi-way Contingency Tables

Module-III

Log-Linear Models-Log-Linear Models for Two-way Tables, On Inference and Fit of Log-Linear Models, Log-Linear Models for Three-way Contingency Tables, Hierarchical Log-Linear Models for Multi-way Tables, Maximum Likelihood Estimation for Log-Linear Models, Model Fit and Selection, Graphical Models, Collapsibility in Multi-way Tables

Module-IV

Generalized Linear Models and Extensions- The Generalized Linear Model (GLM), Log-Linear Model: Member of the GEM Family, Inference for GLMs, Software for GLMS, Independence for Incomplete Tables, Models for Joint and Marginal Distributions. Association Models-Basic Association Models for Two-way Tables, Maximum Likelihood Estimation for Association Models, Association Model Selection, Features of Association Models, Association Models of Higher Order: The RC(M) Model, Software Applications for Association Models, Association Models for Multi-way Tables.

References:

1. Kateri M. (2014). *Contingency Table Analysis: Methods and Implementation using R,* Springer.
2. Agresti A. (2013). *Categorical Data Analysis*, III Edition, John Wiley, New York.

24-322-0411 Directional Data Analysis

Course Outcome (CO)		Cognitivelevel
After completion of this course the student should be able to:		
1.	Understand a circular data and its corresponding distribution theory	Understand
2.	Analyze the various statistical summary statistics associated with circular data	Analyze
3.	Be able to estimate parameter of a circular distribution	Execute
4.	Understand non parametric methods associated analysis of a circular data	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	3			2	3	3	3	
CO2	2	2	2			2	2	2	2	
CO3	2	2	2			2	2	2	2	
CO4	2	2	2			2	2	2	2	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Graphical representation of data, Frequency distribution, Measures of location, circular variance and concentration, Correction for mean grouping, Measures of skewness and kurtosis.

Module-II

Circular models, Distribution theory, Independence, Convolution, Moments, Distributions of an arc, Mixtures, Lattice distributions, Wrapped normal, Cauchy, Poisson distributions, Von Mises, Fisher distribution characteristic functions, Polar distributions, Isotropic random walk on the circle.

Module-III

Point estimation, Cramer Rao type bound, Sufficiency, Methods of estimation, Testing hypothesis from parametric models, Neyman- Pearson and likelihood ratio principles.

Module-IV

Non-parametric methods: Tests for randomness, Goodness of fit, Rayleigh's test, Durand and Greenwood's test, Range test, Kuper's test, Watson's test, Uniform score tests, Runs test, Rank sum test, Tests for dispersion.

References:

1. Mardia K.V. (1972). Statistics of Directional data, Academic Press.
2. Jammalamadaka S. R. & Sengupta A. (2001). Topics in circular statistics (Vol. 5), World Scientific
3. Batschelet E. (1981). Circular Statistics in Biology, Academic Press.
4. Watson G.S (1983). Statistics on Spheres, Wiley.

24-322-0412 STATISTICAL DECISION THEORY

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand the concept of decision rules	Understand
2.	Understand and apply Bayesian concepts	Understand
3.	Able to execute prior elicitation	Execute
4.	Understand concepts of Game theory	Understand
5.	Execute a complete Bayesian decision theoretic problems	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1	3	3	3			2	3	3	3	
CO2	2	1	1			1	1	1	1	
CO3	3	3	3			2	3	3	3	
CO4	3	3	3			2	3	3	3	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Basic elements of a decision problem, Randomized and non-randomized decision rules, Estimation and testing of hypothesis as decision problems, Bayes approach to inference and decision, Loss functions, Prior and posterior distributions, Prior - Posterior analysis for Bernoulli, Poisson and normal processes, Decision principles and Baye's risk.

Module-II

Utility theory, Axioms, Construction of utility functions, Sufficiency, Equivalence of Classical and Bayesian sufficiency, Complete and essentially complete classes of decision rules.

Module-III

Minimax analysis, Basic elements of game theory, General techniques of solving games, Finite games, Supporting and separating hyperplane theorems, Minimax theorem, Minimax estimation for normal and Poisson means.

Module-IV

Admissibility of Bayes and minimax rules, General theorems on admissibility, Robustness of Bayes rules, Invariant decision rules, Location parameter problems, Confidence and credible sets.

References:

1. James O. Berger (1980). Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
2. M.H.DeGroot(1970).Optimal Statistical Decisions, John Wiley.
3. H. Raiffa and R. Schlaifer (2000). Applied Statistical Decision Theory, Wiley Classics.
4. Zellener (1971). An Introduction to Bayesian inference in Econometrics, Wiley.
5. Hayes J, Gand Winkler R I(1976). Probability, Statistics and Decision, Dower.
6. Anthony O' Hagan(1994). Kendall's Advanced theory of Statistics vol.2B, Bayesian Inference, John Wiley

24-322-0413 THEORY OF ENTROPY

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Describe measures of additive entropy and its properties	Understand
2.	Illustrate Conditional entropy relative entropy and mutual Information	Analyze
3.	Describe Renyi entropy, Conditional Renyi entropy	Understand
4.	Discuss non-additive entropy and its properties	Understand
5.	Describe maximum entropy principle	Evaluate
6.	Compute various inequalities in information theory	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1		2						2		
CO2			2				2			
CO3		2			2					
CO4		2			2					
CO5			3				2			
CO6		3			2					

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Measures of Additive Entropy- Statistical Preliminaries, The Shannon entropy, Fadeev characterization, Tverberg characterization, Lee Characterization, Properties of Shannon entropy, Entropy rate, Conditional entropy and information, Chain rules for entropy, relative entropy and mutual information, Jensen's inequality and its consequences, the log sum inequality and its applications, The Renyi entropy and its characterizations, Conditional Renyi entropy.

Module-II

Measures of non-additive entropy- Polynomial entropy and their characterizations, non-polynomial algebraic entropy and characterizations, Transcendental entropy and characterizations, Tsallis entropy- definition and properties.

Module-III

Maximum entropy distributions, examples, Entropy based parameter estimation, Entropy as a criterion for goodness fit, dependence of entropy on sample size. Comparison of other parameter estimation methods with entropy method.

Module-IV

Inequalities in Information Theory- Basic inequalities of information theory, Differential entropy, Bounds on entropy and relative entropy, Inequalities for types, Entropy rates of subsets, Entropy and Fisher information, The entropy power inequality and the Brunn Minkowski inequality, Inequalities for determinants, Inequalities for ratios of determinants

References:

1. Behara M (1990) Additive and non-additive Measures of entropy, Wiley Eastern Limited.
2. Jagat Narain Kapur(1989)Maximum-entropy Models in Science and Engineering, John Wiley & Sons.
3. Robert M Gray (1990) Entropy and Information theory, Springer-Verlag
4. Thomas M.Cover and Joy A. Thomas (1991) Elements of Information Theory, John Wiley & Sons, Inc.
5. Tsallis C.(2023) Introduction to Non-extensive Statistical Mechanics: Approaching a Com-plex World, 2nded.;Springer: NewYork, NY,USA.
6. Vijay P Singh (1998) Entropy based Parameteres timation in hydrology, Kluwer Academic Publishers

24-322-0414 STATISTICS FOR CLINICAL RESEARCH

	Course Outcome (CO)	Cognitivelevel

After completion of this course the student should be able to:

1.	Understand the role of Statistics in Clinical Research	Understand
2.	Understand modern statistical techniques relevant for today's scientific community	Understand
3.	Identify the need for systematic analysis of data in any scientific experiment using statistical packages such as SAS Analysis	Analyze
4.	Practice consultancy on experimental design and field survey	Apply
5.	Solve real life problems using suitable statistical tools in numerous clinical domains	Apply
6.	Understand basic theoretical and applied principles of statistics with adequate preparation to pursue a higher degree or enter job force as an applied Biostatistician	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6	PSO7	PSO8	PSO9	PSO10
CO1		1			1					
CO2		2			1					1
CO3				1						
CO4				2					1	
CO5									2	
CO6		1							1	

1– Slightly/Low, 2 – Moderate/Medium, 3-Substantial/High

Module-I

Drug Discovery and Development Duration: 1 week (4 hours) Introduction to clinical research, history, different phases, clinical data flow and ICH GCP E6 guidelines. Introduction to study documents (Protocol, SAP, CRF) and different activities related to Bios department. Different types of clinical study and study designs.

Module-II

SAS Programming Duration: 3 weeks (12 hours) Introduction to SAS, PDV, SAS statements and general rules of programming. Combining Datasets (Set and Merge), functions and controlling outputs. Data manipulations, various SAS procedures, introduction to SQL and Macros. V

Module-III

CDISC SDTM & ADaM Implementation Duration : 3.5 weeks (14 hours) Introduction to SDTM/ADaM Package, overview, and fundamentals of SDTM/ADaM. Introduction to SDTM/ADaM domains/classes assumptions and types. SDTM/ADaM Specification Development, Pinnacle 21 and submission package.

Module-IV

TLF Report Generation &Advance Biostatistics using SAS Duration: 4 weeks (17hours) Creation of Table/Listing/Figures (TLFs) using REPORT procedure. Introduction to Sensitivity & Tipping point analyses, statistical approaches to handle missing data& common imputation approaches. KM survival analysis using oncology examples and CSR case study using ICH GCP E3 guidelines.

References:

1. Overview of Clinical Research Industry https://www.centerwatch.com/clinical-trials/overview https://www.grandviewresearch.com/industry-analysis/global-clinical trials market#:~:text=Report%20Overview,countries%20is%20fueling% 20 market % 20 growth
2. Overview of Biological Sciences
   https://www.youtube.com/watch?v=URUJD5NEXC8 (Human Cell Structure)
   https://www.youtube.com/watch?v=e_1utfWwdD4 (Human Body System)
   https://www.youtube.com/watch?v=1vaEVcMfa1E (Cellular Death)
   https://www.youtube.com/watch?v=xlvLQtNF-Lk (Cell Multiplication)
   https://www.youtube.com/watch?v=fSEFXl2XQpc (Immune System)
   https://www.youtube.com/watch?v=SgVVGs7nqZA (Diabetes and its types)
   https://www.youtube.com/watch?v=46Xh7OFkkCE (Oncology Introduction)
3. SAS Programming 1 : Free online course with certificate https://support.sas.com/training/outlines/pg1.html#s1=2
4. ICH (International Conference on Harmonization): · E3 (Structure of Clinical Study Report) · E6 (Good Clinical Practice - GCP) · E9 (Statistical Principle for Clinical Trials) Guidelines
5. The Little SAS Book: A Primer, Fifth Edition
6. CDISC SDTM IG V3.3