COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Science – Department of Statistics – M.Sc Statistics & M.Tech in Engineering Statistics – Revised course structure & Outcome Based Education Syllabus – Approved – Orders issued

CONFERENCE SECTION

No.Conf.II/2941/1/AC-Science/2020 Dated, Kochi-22, 27.10.2020

Read: Item No.1(h) of the Minutes of the meeting of the Academic Council held on 08.07.2020

ORDER

The Academic Council at its meeting held on 08.07.2020 along with the recommendations of the Standing Committee resolved to approve vide items read above the revised course structure and Outcome Based Education (OBE) syllabi of the following offered at Department of Statistics under Faculty of Science with effect from 2020 admission onwards as in appendices I & II.

1. M.Sc Statistics
2. M.Tech in Engineering Statistics

Orders are issued accordingly.

Dr.MEERA V.
REGISTRAR

To

1. Dr.K Girish Kumar, Dean, Faculty of Science & Professor, Department of Applied Chemistry, CUSAT, Kochi-22
2. Dr.N.Balakrishna, Professor, Department of Statistics & Chairman, Board of Studies in Statistics, CUSAT, Kochi-22
3. The Head, Department of Statistics, CUSAT, Kochi-22
4. The Controller of Examinations/Joint Registrar (Academic)/Assistant Registrar (Academic)
5. Academic A, C/Exam E, D, Y/Exam Confidential Sections
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M.Sc. (STATISTICS): ACADEMIC PROGRAM.
(with effect from 2020 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 for the needs of the 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 the practical classes and project work. As a part of the course the students are also exposed to various statistical software such as SPSS, MATLAB, SAS and R.

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

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

Eligibility

(i) Successful completion with pass of the first six semesters who have opted integrated M.Sc Statistics of CUSAT.

OR

(ii) B.Sc. degree in Mathematics or Statistics main with at least 55% marks for the optional subjects taken together. The students with Mathematics as main subject should have studied Statistics as subsidiary/main paper.

Duration of the Course **:** Four Semesters
Examination **:** Credit and Semester

Intake During 2020 **:** **20**

2021 onwards : **30** (Including 15 from CAT)

SEMESTER – I

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
20-322-0101	Mathematical Methods for Statistics	C	4	50	50	100
20-322-0102	Probability Theory I	C	4	50	50	100
20-322-0103	Probability Distributions	C	4	50	50	100
20-322-0104	Sampling Theory & Methods	C	4	50	50	100
20-322-0105	Elective: I Statistical Computing	E	3	50	50	100

SEMESTER – II

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
20-322-0201	Statistical Inference I	C	4	50	50	100
20-322-0202	Probability Theory II	C	4	50	50	100
20-322-0203	Stochastic Processes	C	4	50	50	100
20-322-0204	Practical - I and Viva Voce	C	2	100	-	100
Elective – II (Choose any one)						
20-322-0205	Statistics for National Developme nt	E	3	50	50	100
20-322-0206	Reliability Modeling and Analysis.	E	3	50	50	100

SEMESTER – III

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
20-322-0301	Statistical Inference II	C	4	50	50	100
20-322-0302	Multivariate Analysis	C	4	50	50	100
20-322-0303	Applied Regression Analysis	C	4	50	50	100
20-322-0304	Practical - II using SPSS/ MATLAB Project work and Viva Voce.	C	2	50 (practical) + 50 (viva)	-	100
Elective – III (Choose any one)						
20-322-0305	Topics in Stochastic Finance	E	3	50	50	100
20-322-0306	Operations Research-II	E	3	50	50	100
Inter-Departmental Elective						
20-322-0307	Course**	E	3	50	50	100

** Suitable Inter-Departmental Elective will be offered by the Department depending on the demand and the syllabus will be passed by the Academic committee time to time.

SEMESTER - IV

Course Code	Title of Paper	Core/ Elective	Credits	Continuous evaluation marks	End Semester Evaluation Marks	Total marks
20-322-0401	Design and Analysis of Experiments	C	4	50	50	100
20-322-0402	Practical – III using SAS/R , and Viva Voce	C	3	50	50	100
20-322-0403	Project	C	3	100	--	100
Electives - IV, V, VI. (Choose any three)						
20-322-0404	Statistical Quality Assurance	E	3	50	50	100
20-322-0405	Time Series Analysis	E	3	50	50	100
20-322-0406	Lifetime data analysis.	E	3	50	50	100
20-322-0407	Applied Multivariate Statistical Analysis.	E	3	50	50	100
20-322-0408	Statistical Forecasting	E	3	50	50	100
20-322-0409	Inference for Stochastic Processes	E	3	50	50	100

* The Viva Voce examination in 19-322-0402 is to be conducted externally with at least one external examiner (50 marks). The project evaluation is based on a dissertation of 19-322-0403 shall be done in semester IV internally with 50 marks.

Method of Evaluation : 50% weightage for Continuous evaluation and 50% for End semester examination.

Continuous evaluation based on internal tests, assignments, seminars and class attendance as per regulations of the University from time to time.

DETAILED SYLLABUS.

20-322-0101: MATHEMATICAL METHODS FOR STATISTICS

Course Outcome(CO)	Cognitive level
After completion of this course the student should be able to	
1. Demonstrate an 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 linear equations, diagonalize matrices and Characterize quadratic forms	Apply

Module-I

Riemann-Stieltjes Integral:- definition, linear properties, integration by parts, change of variable in a Riemann-Stieltjes integral, reduction to a Riemann integral, step functions as integrators, reduction of a Riemann-Stieltjes integral to a finite sum, Eulers summation formula, monotonically increasing integrators, Riemann's condition, comparison theorems, integrators of bounded variation, sufficient conditions for existence of Riemann-Stieltjes integrals, Mean value theorems of Riemann-Stieltjes integrals, integral as a function of the interval, second mean value theorem for Riemann-Stieltjes integrals.

Module-II

Sequences of functions:- Pointwise convergence of sequence of functions, Uniform convergence and continuity, Cauchy condition for uniform convergence, Uniform convergence of infinite series of functions, Uniform convergence and Riemann-Stieltjes Integration, Uniform convergence and differentiation, Multivariable Calculus:- limit and continuity of multivariable functions, Derivatives of a multivariable function - 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, reduction to normal form, elementary matrices, elementary transformations and elementary matrices, employment of only row (column) transformations, rank of a product, a convenient method for computing the Inverse of a non-singular matrix, Generalized Inverse Matrices:- Definition and existence, an algorithm, Solving linear equations - consistent equations, obtaining solutions, properties of solutions, Penrose inverse, Symmetric matrices - properties of generalized inverse.

Module-IV

Quadratic forms:- definition, Quadratic forms in the real field:- reduction in the real field, canonical forms, classification of quadratic forms and its characteristic properties, necessary and sufficient conditions for a definite form, gram matrices, Characteristic roots and characteristic vectors of a matrix:- determination of characteristic roots and vectors, characteristic sup-spaces 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:- orthogonal reduction of real symmetric matrices, unitary reduction of Hermitian matrices, simultaneous reduction of a pair of quadratic forms, Spectral decomposition of a matrix.

Text Books:

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, NarosaPublshing 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.

Reference Books:

1. Gupta, S.L. and Gupta, N.R. (2003) Principles of Real Analysis, Second edition, Pearson Education (Singapore) Pte. Ltd.
2. Widder, D.A. (1996) Advanced Calculus, Second Edition, Prentice Hall, Inc., New Delhi.
3. Nanda, S. and Saxena, V.P. (2000) Real Analysis, Allied Publishers Ltd.
4. Graybill, F.A. (1969) Introduction to matrices with applications in statistics, Wadsworth Publishing Company, USA.
5. Rao, C.R. (2002) Linear statistical inference and its applications, Second edition, Chapter 1b, 1c.

20-322-0102: PROBABILITY THEORY – I

Course Outcome(CO)	**Cognitive level**

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 Moment inequalities using Expectations	Apply
5.	Concepts of Independence and its use in Multiplication properties, Zero-one laws.	Apply

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).

Text Books:

1. Billingsley, P. (1986) Probability and Measure, Second Edition, John Wiley.

Reference Books:

1. Bhat, B.R. (2011) Modern Probability Theory, Second edition, Wiley Eastern, Chapters 1, 2, 3, 4, 5, 6, 9.

2. Feller, W. (1966) An Introduction to Probability Theory and Its Applications, Volume II, Wiley Eastern.
3. Rao, C.R. (1973) Linear Statistical Inference and Its Applications, Wiley.
4. Rohatgi, V.K. and A.K.E. Salah (2001) Introduction to Probability and Statistics, John Wiley and Sons.
5. Basu, A.K. (1999) Measure Theory and Probability, Prentice-Hall.

20-322-0103: PROBABILITY DISTRIBUTIONS

Course outcome (CO)	**Cognitive level**
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

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.

Text Books:

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

Reference Books:

1. Johnson N.L, Kotz S and Kemp A.W (1992) Univariate discrete distributions, John Wiley.
2. Johnson N.L, Kotz S and Balakrishnan N (1991) Continuous univariate distributions I & II, John Wiley.
3. Johnson N.L, Kotz S and Balakrishnan N (1995) Multivariate Distribution, John Wiley.

20-322-0104: SAMPLING THEORY AND METHODS

Course Outcome (CO)	**Cognitive level**
After completing this course, the student should be able to	
1. Apply various sampling procedures like SRS, Stratified, systematic, Cluster etc., and estimate thepopulation parametresfor 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, DesRaj's sampling strategies under varying probability without replacementsampling	Evaluate/ Apply
4 .Understand various types of errors in surveys, and procedures to rectify them	Apply
5 .Understand quota, networkand adaptive samplings; and evaluate estimator under adaptive sampling	Apply

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

Text Books:

1. Mukhopadhay, P (2009) Theory and methods of survey sampling, Second edition, PHI Learning Pvt Ltd., New Delhi, Relevant sections of Chapters 1-16.
2. Sampath, S. (2001) Sampling theory and methods, Alpha Science International Ltd., India, Chapter 10.

Reference Books:

1. Cochran, W.G. (1999) Sampling Techniques, Third edition, John Wiley & Sons.
2. Des Raj (1976) Sampling Theory, McGraw Hill.
3. Murthy, M.N. (1977) 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.

20-322-0105: ELECTIVE – I

SEMESTER II

20-322-0201: STATISTICAL INFERENCE - I

After completion of this course the students will be able to

Course Outcome(CO)	**Cognitive level**
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

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.

Text Books:

1. E.L.Lehmann (1998) Theory of Point Estimation, John Wiley and Sons.
2. V.K.Rohatgi and A.K.L. Saleh (2001) An Introduction to Probability and Mathematical Statistics, Wiley.
3. B.K. Kale (1999) A First Course in Parametric Inference, Narosa Publishing Company.
4. Robert C.P. and Casella, G (1999) Monte Carlo Statistical Methods, Springer Verlag.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.
2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Mukhopadhay, P. (1999) Mathematical Statistics, New Central Book Agency Pvt. Ltd.

20-322-0202: PROBABILITY THEORY – II

Course Outcome(CO)	**Cognitive level**
After completion of this course students will be able to	
1. Employ Inversion formula, Uniqueness theorem	Apply
2. Illustrate Convergence of distribution function characteristicfunctions,and moments.	Apply
3. Define Covergence of series of independent random variables	Understand
4. Describe different forms of Central limit theorems	Understand
5. Define Conditional expectation and conditional probability	Understand
6. Demonstrate Randon-Nikodym Theorem and its applications.	Apply

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**:** Covergence 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.

Text Books:

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. (1979) Probability Theory, John Wiley, Relevant sections of Chapters 2, 4, 6.

Reference Books:

1. Billingsley, P. (1986) Probability and Measure, Second edition, John Wiley
2. Feller, W. (1976) An Introduction to Probability Theory and its Applications, Volume II Wiley Eastern.
3. Hoffmann - Jorgensen J. (1994) Probability with a view towards Statistics, Chapman & Hall.
4. Loeve M. (1977) Probability Theory, Volume I, Fourth edition, Springer-Verlag
5. Loeve, M. (1978) Probability Theory, Volume II, Fourth edition, Springer-Verlag.
6. Rohatgi, V.K. and Saleh, A.K.E. (2001) An Introduction to Probability and Statistics, John Wiley & Sons.
7. Resnich, S. I. (2005). A Probability Path. Birhauser, Springer.

20-322-0203:STOCHASTIC PROCESSES

Course Outcomes (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Understand the classifications of random processes and concepts such as strict stationarity, wide-sense stationary andergodicity.	Understand
2. Classify the states of a Markov chain and apply 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

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 life time.

Module-IV

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

Text Books:

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, 5 and 8.
2. Bhat, B.R. (2002) Stochastic Processes, second edition, New Age Publication.

Reference Books:

1. Feller, W. (1965, 1968), An Introduction to Probability Theory and its Applications, Volume I and II, Wiley Eastern.
2. Bhat, U.N. (1984) Elements of Applied Stochastic Processes, John Wiley.
3. Cinlar, E. (1975) Introduction to Stochastic Processes, Prentice Hall.
4. Cox, D.R. (1962) Renewal Theory, Methuen.
5. Ross, S. (1996) Stochastic Processes, Second edition, John Wiley
6. Medhi, J. (1994) Stochastic Processes, Second edition, Wiley Eastern.
7. Basu, A.K. (2002) Elements of Stochastic Processes, Narosa Publications.
8. Bhat, U.N. and Gregory Miller (2003) Elements of Applied Stochastic Process, John Wiley.
9. Hoel, P. G., Port, S. C and Stone, C. J. (1986). Introduction to Stochastic Processes. Waveland Press.

20-322-0204: PRACTICAL - I

Course Outcomes (CO)	**Cognitive level**
After completion of this course the students will 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 a parametric models, point and interval estimation of the parameters of those models using real data	Understand
5. Apply topics related to the Elective in the Semester II using real data sets and interpretation of the results.	Apply

Practicals based on topics covered in
20-322- 0104 : Sampling Theory and Methods
20-322- 0201 : Statistical Inference I
20-322- 0203 : Stochastic Processes
20-322- 0205 : Elective II

20-322-0205: ELECTIVE - II

SEMESTER III

20-322-0301: STATISTICAL INFERENCE – II

Course Outcome(C.O)	Cognitive level

After completion of this course the students will 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 bootstrap Confidence intervals	Analyze
8. Examine the non-parametric alternatives for each parametric tests.	Analyze

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.

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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.

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Text Books:

1. Lehmann, E.L. (1998) Testing Statistical Hypothesis, John Wiley.
2. Wald, A. (1947) Sequential Analysis, Doves
3. Gibbons, J.K. (1971) Non-Parametric Statistical Inference, McGraw Hill
4. Rohatgi, V.K. and Saleh, A.K.E. (2001) An Introduction to Probability and Statistics, John Wiley and Sons.
5. Kale, B.K. (1999) A First Course in Parametric Inference, Narosa Publications.

Reference Books:

1. Rao, C.R. (1973) Linear Statistical Inference and its Applications, Wiley.
2. Casella, G and Berger, R.L (2002) Statistical Inference, Second Edition, Thompson-Duxbury Press.
3. Rajagopalan, M and Dhanavanthan, P. (2012). Statistical Inference.
4. Dixit, U. J. (2016). Examples in Parametric Inference with R, Springer.

20-322-0302: MULTIVARIATE ANALYSIS

Course Outcome (CO)	**Cognitive level**
After completion of this course the student should be able to	
1. Describe Multivariate data and its preliminary analysis	Understand
2. Interpret multivariate normal distribution (MVN)	Apply
3. Examine Wishart distribution and its properties	Analyze
4. Explain Hotelling's T^2 and Mahalanobis D^2 statistics	Understand
5. Outline various multivariate testing problems	Analyze
6. Evaluate the above testing problems	Apply
7. Explain classification problem	Understand
8. Describe Principal component analysis (PCA)	Understand

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.

Module-II

Distribution of rectangular co-ordinates, Wishart distribution and its properties, distribution of simple, partial and multiple correlations based on samples from normal population, Hotelling's T^2 and Mahalanobis D^2 statistics, properties of T^2 and D^2, multivariate Fisher-Behren's problem.

Module-III
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-IV
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; principal component analysis- definition, properties and ML estimation; canonical variables, canonical correlation.

Text Books:

1. Anderson, T.W. (1984) An Introduction to Multivariate Statistical Analysis, John Wiley.
2. Johnson, R.A. and Wichern, D.W. (1990) Applied Multivariate Statistical Analysis, Prentice Hall.

Reference Books:

1. Seber, G.A.F. (1977) Multivariate Observations, Wiley.
2. Giri, N., Multivariate Statistical Inference, Academic Publishers.
3. Morrison, D.F. (1976) Multivariate Statistical Methods, John Wiley.
4. Rao, C.R. (1973) Linear Statistical Inference and the Application, Wiley.
5. Rancher, A.C. (1995) Methods of Multivariate Analysis, John Wiley.

20-322-0303: APPLIED REGRESSION ANALYSIS

Course Outcome (CO)	**Cognitive level**
After completion of this unit the student should be able to	
1. Identify a linear and nonlinear 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 Non parametric Regression problem	Analyze
6. Apply Non Parametric Regression techniques	Apply

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 variables, Subset selection of explanatory variables, stepwise regression and Mallows C_p-statistics, Introduction to non-parametric regression.

Unit-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**.**

Text Books:

1. Montgomery, D.C., Peck, E.A. and Vining, G.G. (2001) Introduction to Regression Analysis, Third edition. Wiley. Chapter 2, 3,
2. Seber, A.F. and Lee, A.J. (2003) Linear Regression Analysis, John Wiley, Relevant sections from chapters 3, 4, 5,

Reference Books:

1. Searle, S.R. (1971) Linear models, John Wiley & Sons, Inc.
2. N.Draper and H. Smith (1986) Applied Regression Analysis – John Wiley & Sons.
3. Fox, J. (1984) Linear Statistical Models and Related methods, John Wiley, Chapter 5.
4. Christensen, R. (2001) Advanced Linear Modeling, Chapter 7.
5. B.Abraham and Ledotter, J. (1983) Statistical Methods for Forecasting, John Wiley & Sons.

20-322-0304: PRACTICAL - II USING SPSS/MATLAB

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Understand various tools in SPSS/Matlab	Understand
2. Apply different statistical testing problems using real data sets and interpretation of the results	Analyze
3. Apply different multivariate techniques using real data sets 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

Practicals based on topics covered in
20-322- 0301 ; Statistical Inference II
20-322- 0302 : Multivariate Analysis
20-322- 0303 : Applied Regression Analysis
20-322- 0305 : Elective III

20-322-03--: ELECTIVE - III

SEMESTER IV

20-322-0401: DESIGN AND ANALYSIS OF EXPERIMENTS

Course Outcome (CO)	Cognitive level
After completing the course, the student should be able to	
1. Understand the basic principles and guidelines of Design of experiments	Apply
2. Design and analyze CRD RBD,LSD and Greaco LSD	Apply
3. Apply incomplete 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

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.

Text Books:

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 Volume I, John Wiley.

Reference Books:

1. Joshi D.D. (1987) Linear Estimation and Design of Experiments, Wiley Eastern.
2. Chakrabarti, M.C. (1964) Design of experiments, ISI, Calcutta.

20-322-0402: PRACTICALS - III USING SAS/R AND VIVA-VOCE

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will 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

Practical based on topics covered in

20-322-0401 : Design and Analysis of Experiments.
Elective IV, Elective V, Elective VI.

20-322-0403: Project

19-322-04--: Elective IV

19-322-04--: Elective V

19-322-04--: Elective VI

LIST OF ELECTIVES

Course Name-20-322-0105: Data Analytics using R

Course Outcome (CO)	**Cognitive level**

After completion of this course the students will 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 programs using R to perform routine and specialized data manipulation /management and analysis tasks	Evaluate

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).

Text Book:

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.

Reference Books:

1. Chambers, J. M. (2008). Software for Data Analysis-Programming with R. Springer-Verlag, New York.
2.Jammalamadaka, S. R. (2007). Essential Statistics with python and R.Kendal Hunt publishing.

20-322-0205 :STATISTICS FOR NATIONAL DEVELOPMENT

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will 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 measurepovertythrough measures of incidence and intensity combined.	Analyze
5. Define components of Time series Determine the trend, analyze seasonal	Remember
6. Fluctuations, construct seasonal indices Measure cyclical movement.	Analyze

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.

Reference Books:

1. Basic Statistics Relating to Indian Economy (CSO), 1990 - Current Indian Statistics
2. Cox PR (1957) Demography, Cambridge University Press
3. Croxton F E and Crowder D J (1967) Applied General statistics, Prentice - Hall India.
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, Series M-12

20-322-0305: TOPICS IN STOCHASTIC FINANCE

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will be able to	
1. Define the terms: interest rate, options, pay-off, arbitrage, geometric Brownian 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 via utility 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

Module-I

Interest rate andPresent 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 multiperiod binomial models, Crude oil data, Autoregressive moving average models for returns, Mean reversion.

Text Book:

1.Sheldon M. Ross (2003).An Elementary Introduction to Mathematical Finance**.** Cambridge University Press.

Reference Books:

1. A.N. Shiryave (1999). Mathematical Finance, Theory and Practice, World Scientific.
2. David Ruper (2004). Statistics and Finance- An Introduction, Springer International Edition.

3. Fima C. Klebener (1997). Introduction to Mathematical Finance. World Scientific
4. John C. Hull (2008). Options, Futures and other derivatives. Pearson Education India.

20-322-0306: OPERATIONS RESEARCH II

Course Outcome (CO)	Cognitive level
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. Solve non-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

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).

Text Books:

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 Man Mohan (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.

Reference Books:

1. Ravindran A, Philips D.T and Soleberg J.J. (1997) Operation Research - Principles and Practice, John Wiley & Sons.
2. Sinha, S.M. (2006) Mathematical programming theory and methods, Elsevier, a division of Reed Elsevier India Pvt. Ltd., New Delhi.
3. Paneerselvam, R. (2008) Operations Research, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi.

20-322-0206: RELIABILITY MODELING AND ANALYSIS

Course Outcome (CO)	**Cognitive Level**
After completing the 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 life time 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, PF 2 , 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 samplesthrough the Bayesian Estimation.	Evaluate

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

Non monotonic failure rates and mean residual life functions, Study of life time models viz. exponential,Weibull, lognormal, generalized Pareto, gamma with reference to basic concepts and ageing characteristics; Bath tub and upside down bath tub failure rate distributions.

Module-III

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, PF 2 , WPQD.

Module-IV

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

Text Books:

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.

Reference Books:

1. Marshall, A.W. and Olkin, I. (2007) Life Distributions, Springer
2. Galambos, J. and Kotz, S. (1978) Characterization of Probability distributions, Springer
3. Lawless, J.F. (2003) Statistical Models and Methods for Life Data, Wiley.

20-322-0404: STATISTICAL QUALITY ASSURANCE

Course Outcome (CO)	**Cognitive level**
After completing the coursethe 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	

Distinguish between them. Apply

3.Explain acceptance sampling by variables , Sampling Plans for a single and double specification limits with known and unknown variance, Sampling plans with double specification limits. Apply

4.Compare sampling plans by variables and attributes and Continuous sampling plans I, II & III. Evaluate

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.

Text Books:

1. Montgomery, R.C. (1985). Introduction to Statistical Quality Control, Fourth edition,Wiley.
2. Mittag, H.J. & Rinne, H. (1993) Statistical Methods for Quality Assurance, Chapman &Hall, Chapters 1, 3 and 4,15
3. The ISO 9000 book, Second Edition, Rabbit, J T and Bergle, PA Quality resources,Chapter-I
4. Schilling, E.G. (1982) Acceptance Sampling in Quality Control, Marcel Dekker.
5. AmitavaMitra - Fundamentals of Quality Control and Improvement – PearsonEducation Asia 2001 – Chapter 12 (relevant parts)

Reference Books:

1. Duncan, A.J. (1986) Quality control and Industrial Statistics.
2. Grant E.L. and Leaven Worth, R.S. (1980) Statistical Quality Control, McGraw Hill.
3. Chin-Knei Cho (1987) Quality Programming, John Wiley.

20-322-0405: TIME SERIES ANALYSIS

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will 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 set up.	Analyze
9. Compute Smooth and filter by Kalman algorithm.	Apply
10. Identify a model for the given time series.	Analyze

Module-I

Characteristics of time series: Time series as a discrete parameter stochastic process, Auto-correlation (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. (15 hours)

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. (20 hours)

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. (15 hours)

Module-IV

State space models: Filtering, smoothing and forecasting using state space models, Kalman smoother, Maximum likelihood estimation, Missing data modifications. (15 hours).

Text Books:

1. Shumway, R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications. Springer.
2. Box, G. E. P. Jenkins, G. M. and Reinsel, G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.
3. Brockwell, P.J and Davis R.A. (2006) Time Series: Theory and Methods, 2nd edn. Springer-Verlag.

Reference Books:

1. Abraham, B. and Ledolter, J.C. (1983) Statistical Methods for Forecasting, Wiley.
2. Anderson, T.W (1971) Statistical Analysis of Time Series, Wiley.
3. Fuller, W.A. (1978) Introduction to Statistical Time Series, John Wiley.
4. Kendall, M.G. (1978) Time Series, CharlerGraffin.
5. Tanaka, K. (1996) Time Series Analysis, Wiley Series.
6. Chatfield, C. (2004) The Analysis of Time Series - An Introduction, Sixth edition, Chapman and Hall.

20-322-0406: LIFETIME DATA ANALYSIS

Course Outcomes (CO)	**Cognitive level**
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.	Analysis
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

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, PointwiseConfidence 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.

Text Books:

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 Editon, John Wiley & Sons, Relevant Sections of the Chapters 9.

Reference Books:

1. Kalbfleisch J.D and Prentice, R.L. (2002) The Statistical Analysis of Failure Time Data, Second Edition, John Wiley & Sons Inc.
2. Hosmer Jr. D.W and Lemeshow S (1999) Applied Survival Analysis - Regression Modelling of Time to event Data, John Wiley & Sons. Inc.
3. Nelson. W (2003) Applied Life Data Analysis.
4. Miller, R.G. (1981) Survival Analysis, John Wiley.
5. Deshpande, J .V. and Purohit, S. G. (2006). Lifetime Data: Statistical Models and Methods. World Scientific.

20-322-0407: APPLIED MULTIVARIATE STATISTICAL ANALYSIS

After completion of this course the student should be able to

Course Outcome (CO)	**Cognitive level**
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

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.

Text Books:

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. Dillon, W.R. and Goldstein, M (1984) Multivariate Analysis, John Wiley, Relevant sections from Chapter 12.

Reference Books:

1. Seber G.A.F. (1983) Multivariate Observations, Wiley.
2. Tabachnick, B.G. and Fidell, L.S. (2018) Using multivariate statistics, Sixth edition, Pearson India Education Services Pvt Ltd, India.
3. Gnandesikan, R., Methods of Statistical Data Analysis of Multivariate Observations, Wiley.
4. Jambu, M and Lebeaux M.O., Cluster Analysis and Data Analysis.
5. Lebart, Lmorinean, A. and Warwick K.M., Multivariate Descriptive Statistical Analysis, John Wiley.
6. Davison, Multidimensional Scaling, John Wiley.
7. Morrison D.F., Multivariate Statistical Methods, McGraw Hill.
8. Rencher, A.C. (1995) Methods of Multivariate Analysis, John Wiley.

20-322-0408: STATISTICAL FORECASTING

Course Outcome(C.O)	**Cognitive level**
After completion of this course the students will be able to	
1. Define various types of forecasts 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 Kalman filters.	Analyze
9. Choose a model and construct forecast formula for a given time series.	Apply

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.

Text Books:

1. Abraham B and Ledolter, J (2005) Statistical Methods for Forecasting, John Wiley and Sons, New York.
2. Shumway, R. H and Stoffer, D. S. (2006). Time series Analysis and its Applications. Springer.
3. Montegomery, D. C., Jennings, C. L. and Kulachi, M. (2008). Introduction to Time series analysis and Forecasting.

Reference Books:

1. Pankratz, A. (1983) Forecasting with univariate Box-Jenkins models, John Wiley Sons, New York
2. Makridakis, S. and Wheelwright, S.C. (1998) Forecasting Methods and Applications, John Wiley and Sons
3. Box, G. E. P. Jenkins, G. M. and Reinsel, G. C. (1994). Time Series Analysis: Forecasting and Control, Pearson Education.
4. Brockwell, P.J. and Davis, R.A. (2013) Introduction to Time Series and Forecasting, second edition, Forth Edition, Springer.

20-322-0409: INFERENCE FOR STOCHASTIC PROCESSES

Course Outcome (CO)	**Cognitive level**
After completion of this course the students will 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
5. Give examples for processes satisfying the regularity conditions under which estimators and test functions behave well.	Understand
6. Identify a suitable stochastic model for the given situation.	Analyze

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.

Unit-IV

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

Text Books:

1. Basava, I.V. and Prakasa Rao, B.L.S. (1980) Statistical Inference for Stochastic Processes Academic Press Chapters 1-7.

Reference Books:

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