

M.Sc Statistics

(Effective from the admitted batch of 2021-22)

Scheme and Syllabus



**DEPARTMENT OF STATISTICS
COLLEGE OF SCIENCE AND TECHNOLOGY
ANDHRA UNIVERSITY, VISAKHAPATNAM
TITLE OF THE PROGRAM: M.Sc. STATISTICS**

PROGRAM OUTCOMES:

PO 1: To obtain sound scientific knowledge in Statistical and applied aspects of Statistics.

PO 2: To describe the phenomenon of various systems and processes.

PO 3: To handle and analyse data bases with sound computer skills and develop interpretations.

PO 4: To model the random phenomenon of various systems and processes using Statistical analysis.

PO 5: To become a data scientist for assessing in decision making.

PO 6: To get a wide range of opportunities and private, corporate and government sector organisations.

PO 7: To analyse and develop strategies for industrial and service organisations.

PO 8: To be able to train non statisticians to handle Statistical and data analytics.

PROGRAM SPECIFIC OUTCOMES:

PSO 1: To obtain sound statistical knowledge for data analysis and developing inferences.

PSO 2: To design and develop models for various phenomenon and obtaining optimal strategies.

PSO 3: To become a good data scientist.

PSO 4: To become competent to pursue research or a career in Statistics.

PSO 5: To inculcate scientific attitude and enriched with interdisciplinary and transdisciplinary applications of Statistics for developing sound decisions.

Semester	Paper	Marks	Credits	
I	1.1 Probability and Distributions	80+20	4	
	1.2 Estimation Theory	80+20	4	
	1.3 Sampling	80+20	4	
	1.4 C –Programming	80+20	4	
	Practical Examination (Practical 150+Record 50)	200	8	
	Viva-Voce	25	1	
	Total	625	25	
II	2.1 Multivariate Analysis	80+20	4	
	2.2 Testing of Hypothesis	80+20	4	
	2.3 Stochastic Processes	80+20	4	
	2.4 Design and Analysis of Experiments	80+20	4	
	Practical Examination (Practical 150+Record 50)	200	8	
	Viva-Voce	25	1	
	Total	625	25	
III	3.1 Operations Research – I	80+20	4	
	3.2 Linear Models and Regression Analysis Two optional papers (3.3 and 3.4) are to be chosen from the following five optional papers a) Demography b) Industrial Statistics and Quality Control c) Time Series Analysis d) Computer Intensive Statistical Methods e) Machine Learning	80+20	4	
	3.3 Optional Paper-1	80+20	4	
	3.4 Optional Paper-2	80+20	4	
	Practical Examinations (Prac.100+Rec.50)	150	6	
	Viva-Voce	25	1	
	MOOCS/SWAYAM Course		4	
	Intellectual Property Rights		2	
		Total	625	29
	IV	4.1 Operations Research – II	80+20	4
4.2 Computer Programming –C++ Two optional papers (4.3 and 4.4) are to be chosen from the following five optional papers a) Econometrics b) Actuarial Statistics c) Knowledge Discovery and Data Mining d) Reliability and Survival Analysis e) Biostatistics		80+20	4	
4.3 Optional Paper-1		80+20	4	
4.4 Optional Paper-2		80+20	4	
Project Work		100	4	
Practical Examination (Prac.100+Rec.50)		150	6	
Viva-Voce		25	1	
MOOCS/SWAYAM Course			4	
Research Methodology			2	
		Total	675	33

**SYLLABUS
M. Sc. STATISTICS
I SEMESTER
WITH EFFECT FROM 2021- 2022 ADMITTED BATCH OF STUDENTS**

Paper – 1.1: PROBABILITY AND DISTRIBUTIONS

Course Outcomes:

- CO1: To be able to understand the concepts of probability and probability measures.
- CO2: To get expertise in analyzing the random phenomenon through convergence of random variable.
- CO3: To be able to derive and analyse characteristic function of the random variable and apply to analyze the behaviour of the random phenomenon.
- CO4: To be able to understand different types of inequalities associated with mathematical expectations.
- CO5: To be able to understand the concept of law of large numbers and their applications.
- CO6: To get expertise in understanding the advanced probability distributions and utilizing them to model the random phenomenon.
- CO7: To understand multivariate distributions and its applications in data analysis.
- CO8: To be acquainted with distributions of order statistics of various random variable and their applications.

Course Specific Outcomes:

- CSO1: Able to get thorough understanding of probability analysis for random events.
- CSO2: In depth knowledge of probability theory in various types of convergence of random variables.
- CSO3: Thorough understanding of probability distributions and their properties.
- CSO4: Acquainting knowledge on multivariate normal distribution and order statistics.

Learning Outcomes:

- LO1: Able to analyse data sets with sound probability theory for scientific knowledge discovery.
- LO2: Able to understand and analyse random phenomenon of different events.
- LO3: Able to model stochastic nature through probability distributions.
- LO4: Able to apply probability and distribution theory in solving practical problems.
- LO5: Able to support decision making through data analysis.

UNIT-I: Classes of sets, field, Sigma-field, minimal sigma-field, Borel field, probability measure to sigma field, Lebesgue measure, Lebesgue-Stieltjes measures. Measurable functions, Borel function.

UNIT-II: Convergence of Random variables: Convergence in probability, criterion for convergence in probability, closure under arithmetic operations, convergence almost surely, comparison with convergence in probability; convergence in distribution, convergence in r th mean. Characteristic function, properties of characteristic functions, inversion formulae.

UNIT-III: Mathematical expectation, Moments of random variable, conditional expectation, Basic Markov's, Chebyshev's, Holder's Minkowski's and Jensen's inequalities. Law of large numbers: Chebyshev's and Khinchin's forms of WLLN. Kolmogorov's SLLN.

UNIT-IV: Weibull distribution; Definition, properties of Weibull distress, moment generating functions, characteristic function, Hazard functions, Laplace distributions; Definitions, properties

of Laplace Distributions, moment generating functions, characteristic function, logistic distributions; definitions properties of logistic distributions, moment generating functions, characteristics functions.

UNIT-V: Multivariate normal, distribution, definition, Bivariate normal distribution, as a particular case, moments, characteristic function, conditional and marginal distributions. Distributions of Order Statistics from exponential and normal distributions.

Text Books:

Bhat, B.R.: Modern Probability Theory, Wiley Eastern Ltd.

Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics, John Wiley.

Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory Volume-I, The World Press Pvt. Ltd., Calcutta.

Reference Books:

Billingsley, P. (1986): Probability and Measure. Wiley.

Kingman, J F C and Taylor, S. J. (1966): Introduction to Measure and Probability. Cambridge University Press.

David, H.A (1981): Order Statistics, 2nd Ed, John Wiley.

Feller, W (1966): Introduction to probability theory and its applications, Vol.II, Wiley.

Cramer H (1946): Mathematical Methods of Statistics, Princeton University Press.

Morrison, D.F (1976): Multivariate Statistical Methods, 2nd Ed, McGraw Hill.

Mardia, K.V., Kent J.T and Bibby J.M. (1979) : Multivariate Analysis, Academic Press.

Anderson, T.W (2003): An introduction to Multivariate Statistical Analysis, 3rd Ed ,John Wiley.

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Paper – 1.2: ESTIMATION THEORY

Course Outcomes:

- CO1: Able to understand the concepts of unbiasedness and consistency.
- CO2: Able to derive lower bound to the variance of an unbiased estimator using Cramer-Rao inequality and Bhattacharya bounds.
- CO3: Able to learn the concepts of MVUE, MVBUE and UMVUE.
- CO4: To make familiar with the concept of sufficiency.
- CO5: Can calculate estimates of parameters using ML method.
- CO6: To acquaint with estimation of parameters of censored and truncated distributions.

Course Specific Outcomes:

- CSO1: To acquire knowledge of a good estimator.
- CSO2: To get in depth knowledge of theoretical foundation of point estimation.
- CSO3: To get knowledge of Interval estimation.
- CSO4: To acquaint with exponential and Pitman families.

Learning Outcomes:

- LO1: Acquire knowledge of estimation theory which is the basis of higher level mathematical statistics.
- LO2: Able to construct an estimator that exhibits optimal properties.
- LO3: Able to estimate parameters using the observed data set.
- LO4: Able to secure in depth knowledge of estimation of parameters of censored and truncated distributions.
- LO5: Can identify appropriate estimation techniques to perform correct statistical analysis.

UNIT-I: Point Estimation: Concepts of Unbiasedness, Consistency, minimum variance unbiased estimation, Information in a sample, Cramer-Rao inequality, efficiency of an estimator, Chapman-Robin's inequality and Bhattacharya bounds, definition of CAN estimator.

UNIT-II: Concept of sufficiency – single parameter and several parameter cases. Fisher-Neyman Factorization theorem, Minimal sufficient statistic, exponential families and Pitman families. Invariance property of sufficiency under $1 - 1$ transformation of sample space and parameter space.

UNIT-III: Distributions admitting sufficient Statistics, Rao-Blackwell Theorem, Completeness, Lehman-Scheffe Theorem, joint sufficiency (regular case).

UNIT-IV: Method of maximum likelihood, CAN estimators for one-parameter Cramer family. Cramer-Huzurbazar theorem, Solution of likelihood equations, Method of scoring. Connection between MLE's and efficient estimators, MLE's and sufficient estimators.

UNIT-V: Censored and truncated distributions: Type 1 and Type 2 Censoring for normal and exponential distributions and their MLE's. Interval estimation: Confidence Intervals, using pivots; shortest expected length confidence intervals.

Text Books:

Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory Volume -II, The World Press Pvt. Ltd., Calcutta.

Rohatgi, V. (1998): An Introduction to Probability and Mathematical Statistics, Wiley Eastern Ltd., New Delhi.

Kale, B.K. (1999): A First Course on Parametric Inference, Narosa Publishing house.

Reference Books:

Lehmann, E.L. (1986): Theory of Point Estimation. John Wiley

Rao, C.R. (1973): Linear Statistical Inference and its Applications. John Wiley

Dudewicz, E.J. and Mishra, S.N. (1988): Modern Mathematical Statistics. Wiley, Int. Student edition.

Lawless, J.F (2003): Statistical Models and Methods for Lifetime Data, 2nd Ed, John Wiley & Sons

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Paper – 1.3: SAMPLING THEORY

Course Outcomes:

- CO 1: Able to familiarize with advanced concepts of Probability Proportional to Size Sampling.
- CO 2: Understand the selection of PPS sampling and able to calculate the Horvitz and Thompson estimator.
- CO 3: Able to estimate population mean and variance of systematic sample when population exhibits linear trend.
- CO 4: Understand Cluster sampling and their applications by estimation of population mean and variance.
- CO 5: Understand the concept of ratio and regression methods of estimation.
- CO 7: Acquainted with multiphase and multistage sampling

Course Specific Outcomes:

- CSO 1: Able to understand the basic concepts of various probability sampling techniques.
- CSO 2: Understand Probability proportionate to size sampling and able to calculate Yates and Grundy's estimator.
- CSO 3: Able to understand systematic sampling technique.
- CSO 4: Able to apply two stage sampling technique and also Two-stage PPS sampling technique.
- CSO 5: Able to apply the ratio and regression methods of estimation in stratified random sampling.
- CSO 6: Understand the sampling and non-sampling errors.

Learning Outcomes:

- LO 1: Acquire knowledge to assess different sampling methods and their applications.
- LO 2: Students acquire the basic knowledge to understand different advanced techniques of sampling methods.
- LO 3: Student can construct mathematical models by applying different sampling techniques to the real life situations.
- LO 4: Students acquire the theoretical as well as practical knowledge of field study to analyze the data, interpret the results and draw valuable conclusions.

UNIT-I: Selection with varying probabilities, PPS sampling, Horvitz and Thompson estimator, Yates and Grundy's estimator, Midzuno -Sen Sampling Scheme.

UNIT-II: Systematic Sampling: Estimation of population mean and its variance, Methods for populations with linear trend: Yates end correction, Modified systematic sampling, balanced systematic sampling, centrally located sampling. Circular systematic sampling.

UNIT-III: Cluster sampling: Estimation of population mean and its variance, efficiency of cluster sampling. Determination of optimal cluster size. Estimation of proportion. Cluster sampling with varying sizes.

Two-stage sampling: Two-stage sampling with equal first stage units. Estimation of mean and its variance. Optimum allocation. Three stage sampling with equal probabilities. Two-stage-pps sampling.

UNIT-IV: Ratio estimator: Introduction, Bias and Mean square error, Estimation of variance, confidence interval, comparison with mean per unit estimator, Ratio estimator in stratified random sampling.

Difference estimator and Regression estimator: Introduction, Difference estimator, Difference estimator in stratified sampling. Regression estimator, Comparison of regression estimator with mean per unit estimator and ratio estimator. Regression estimator in stratified sampling.

UNIT-V: Multiphase Sampling: Introduction, Double sampling for Difference estimation. Double sampling for ratio estimation. Double sampling for regression estimator, Optimum allocation varying probability sampling. Non sampling errors: Sources and types of non Sampling errors, Non response errors, techniques for adjustment of non response, Hansen and Hurwitz Technique, Deming's Model.

Text Books:

F.S. Chaudhary: Theory and Analysis of Sample Survey Designs, New Age International Publishers, Delhi.

Des Raj, Pramod Chandak (1998): Sample survey Theory, Narosa Publishing House, Delhi

Cochran, W.G.: Sampling Techniques.

Murthy, M.N.: Sampling Theory and Methods

Primal Mukhopadhyay: Theory and Methods of Survey Sampling. Prentice-Hall of India Private limited – New Delhi.

Sukhatme, P.V. and Sukhatme, B.V.: Sampling Theory of Surveys with Applications.

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Paper – 1.4: R PROGRAMMING

Course Outcomes:

- CO1: Understand the atomic types of R, different methods of creating and filtering of vectors, manipulation of text data, factor data and dates.
- CO2: Understand how to create, subset and modify data structures like matrices, arrays, data frames and lists. Understand how to read data into and out of R.
- CO3: Understand the control statements of R, writing functions and scripts in R and debugging features of R. Understand the use of apply family of functions.
- CO4: Understand the use the high-level plotting functions in R to create graphs in base R and the low-level plotting functions to customize the graphs.
- CO5: Understand the use of built-in functions to perform hypotheses testing, correlation and regression analysis, and ANOVA.

Course Specific Outcomes:

- CSO1: Able to create and manipulate vectors, matrices, arrays, data frames and lists. Should be able to work with character data, factor data and dates.
- CSO2: Able to write scripts and function in R and read data from .csv files, EXCEL files and SPSS files.
- CSO3: Able to distinguish between high-level and low-level plotting functions available in base R.
- CSO4: Able to use built-in functions to answer questions relating to probability distributions, parametric and nonparametric hypothesis testing, correlation and regression analysis, and one-way and two-way ANOVA.

Learning Outcomes:

- LO1: Able to work with data types of the type numeric, factor, text and dates.
- LO2: Able to create and manipulate the various data structures such as vectors, matrices, arrays, data frames and lists.
- LO3: Able to get data into and out of R, write R scripts and effectively use the various R functions.
- LO4: Able to create and customize graphs in R.
- LO5: Able to use the built-in functions to perform various hypotheses testing problems, correlation and regression analysis, and ANOV

UNIT-I: Familiarizing with R environment, Using R console as a calculator, R atomic types, methods of creating vectors, combining vectors and repeating vectors, different ways of subsetting vectors using indexing, names and logicals. Arithmetic and logical operations. Using character vectors for text data, manipulating text using `strsplit()`, `paste()`, `cat()`, `grep()`, `gsub()` functions; handling factor data. Working with dates.

UNIT – II: Creating Matrices, getting values in and out of matrices, performing matrix calculations; Working with multidimensional Arrays; creating data frames, getting values in and out of data frames, adding rows to data frame, adding variables to data frame; creating lists, extracting components from a list, changing values of components of lists. Getting data into and out of R - reading data in CSV files, EXCEL files, SPSS files and working with other data types. Getting data out of R – working with `write.csv()` and `write.table()` functions.

UNIT – III: Writing Scripts and functions in R. writing functions with named, default and optional arguments. functions using as arguments. Debugging your code. Control statements in R – conditional control using `if`, `if-else`, `ifelse`; looping control using `for`, `while`, `repeat`; transfer of control using `break` and `next`. Manipulating and processing data - creating subsets of data, use of `merge()` function, sorting and ordering of data. Group manipulation using apply family of functions - `apply`, `sapply`, `lapply`, `tapply`.

UNIT – IV: Base graphics. Use of high-level plotting functions for creating histograms, scatter plots, box-whiskers plot, bar plot, dot plot, Q-Q plot and curves. Controlling plot options using low-level plotting functions - Adding lines, segments, points, polygon, grid to the plotting region; Add text using `legend`, `text`, `mtext`; and Modify/add axes, Putting multiple plots on a single page.

UNIT - V - Working with probability distributions - normal, binomial, Poisson and other distributions. Summary statistics, hypothesis testing - one and two-sample Student's t-tests, Wilcoxon U-test, paired t-test, paired U-test, correlation and covariance, correlation tests, tests for association- Chi-squared test and goodness-of- fit tests. Formula notation, one-way and two-way ANOVA and post-hoc testing, graphical summary of ANOVA and post-hoc testing, extracting means and summary statistics; linear regression.

Text Books:

1. Mark Gardener (2012), Beginning R - The Statistical Programming Language, Wiley India Pvt Ltd.
2. Andrie de Vries and Joris Meys (2015), R Programming for Dummies, Wiley India Pvt Ltd.
3. Jared P. Lander (2014), R For Everyone - Advanced Analytics and Graphics, Pearson Education Inc.

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Paper – 2.1: MULTIVARIATE ANALYSIS

Course Outcomes:

- CO1: Understand Wishart distribution, Hotelling's T^2 and Mahalanobis' D^2 statistic for testing hypothesis relating to multivariate normal distribution.
- CO2: Understand classification and discriminant procedures, correctly classify new subjects into given classes, tests associated with discriminant functions, probability of misclassification and k-nearest neighbour classification.
- CO3: Students will be trained in finding correlations between two sets of variables and also dimension reduction using principal components.
- CO4: Investigate the nature of dependence among several variables and find out the underlying factors that affect variations of multivariate data.
- CO5: To find out groups of similar objects or variables based upon measured characteristics and also understand and interpret results from multidimensional scaling.

Course Specific Outcomes:

- CSO1: Able to use Wishart distribution, Mahalanobis D^2 and Hotelling's T^2 , and their use in tests of hypothesis relating to multivariate normal distribution.
- CSO2: Able to understand the theory, properties of discriminant analysis, principal component analysis, canonical correlation,
- CSO3: Able to understand the theory and properties of factor analysis, cluster analysis, multidimensional scaling.
- CSO4: Able to use of statistical software to analyze the multivariate data choosing an appropriate multivariate technique.

Learning Outcomes:

- LO1: Describe Wishart distribution and its properties. Use Hotelling's T^2 and Mahalanobis D^2 statistics for testing hypotheses regarding parameters of multivariate normal distribution.
- LO2: Understand the basic ideas behind classification and discrimination procedures and their evaluation methods.
- LO3: Understand the theoretical properties and appropriate applications of techniques such as principal component analysis, and canonical correlation analysis.
- LO4: Understand the factor analysis as a statistical model and the various estimation methods of factor loadings, various rotation methods and their use and importance.

LO5: Understand the various hierarchical and non-hierarchical clustering methods and their application. Understand the classical and non-metric multidimensional scaling, their fit measures and applications.

LO6: Use of popular statistical packages in analyzing the real datasets.

UNIT-I: Definition of Wishart matrix and its properties, Mahalanobis Distance, Null distribution of Hotelling's T^2 statistic. Application in tests on mean vector for one and more multivariate normal populations and also on equality of the components of a mean vector in a multivariate normal population.

UNIT-II: Classification and discrimination procedures for discrimination between two multivariate normal populations, sample discriminant function, tests associated with discriminant functions, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations. K-nearest neighbor classification.

UNIT-III: Principal components, Dimension reduction, Canonical variables and canonical correlation -definition, use, estimation and computation.

UNIT-IV: Factor Analysis: The orthogonal factor model, Methods of estimating factor loadings - the principal component method, principal factor method, iterated principal factor method, maximum likelihood estimation. Factor rotation: orthogonal factor rotation, varimax rotation, quartimax rotation, oblique rotation, criteria for determining number of common factors. Factor scores.

UNIT-V: Cluster Analysis: Hierarchical Clustering, methods single, complete and average linkage methods, Centroid method and Ward's method. Non-Hierarchical Methods- K-means algorithm. Multidimensional scaling.

Note: Practical exercises must be based on statistical package only.

Text Books:

Anderson, T. W. (1983): An Introduction to Multivariate Statistical Analysis. 3rd Ed. Wiley.

Seber, G. A. F. (1984): Multivariate Observations. Wiley.

Johnson, R and Wichern (1992): Applied Multivariate Statistical Analysis, Prentice Hall, India, 6th edition.

Reference Books:

Gin. N. C. (1977): Multivariate Statistical Inference. Academic Press

Kshirsagar, A. M. (1972): Multivariate Analysis. Marcel Dekker.

Morrison, D. F. (1976): Multivariate Statistical Methods. 2nd Ed. McGraw Hill

Muirhead, R. J. (1982): Aspects of Multivariate Statistical Theory, J. Wiley.

Rao, C. R. (1973): Linear Statistical Inference and its Applications. 2nd ed. Wiley.

Sharma. S. (1996): Applied Multivariate Techniques. Wiley.

Srivastava, M. S. and Khatri, C. G. (1979): An Introduction to Multivariate Statistics. North Holland.

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Paper – 2.2: TESTING OF HYPOTHESIS

Course Outcomes:

- CO1: Able to learn construction of null and alternative hypothesis.
- CO2: Able to calculate probabilities of type I and type II errors.
- CO3: To acquaint knowledge of Neyman – Pearson testing of hypothesis.
- CO4: To obtain MP, UMP and UMPU tests.
- CO5: To understand concepts of likelihood ratio tests.
- CO6: To understand concept of SPRT and Non Parametric tests.

Course Specific Outcomes:

- CSO1: To acquire knowledge of Neyman – Pearson testing of hypothesis.
- CSO2: To acquainted with Monotone likelihood ratio tests.
- CSO3: To illustrate likelihood ratio criterion for one sample and K sample problems.
- CSO4: To construct O.C and A.S.N for Wald's SPRT.

Learning Outcomes:

- LO1: Able to demonstrate about errors in testing of hypothesis.
- LO2: Application of UMP and UMPU tests for discrete and continuous distributions.
- LO3: Able to identify proper testing procedure for a given data set and to perform appropriate statistical analysis using different tests.
- LO4: With the basic knowledge of testing of hypothesis student can learn advanced inferential aspects.

UNIT-I: Neyman – Pearson theory: Lemma using critical functions. Uniformly most powerful tests, their relation with sufficient statistics.

UNIT-II: Monotone Likelihood ratio and UMP tests for one-sided hypothesis, Composite hypothesis. Unbiased tests, uniformly most powerful unbiased tests. Type A and Type A_1 regions.

UNIT-III: Likelihood ratio criterion, its asymptotic distribution, one sample, two samples and K – sample problems. Linear hypothesis. Walds's SPRT: Prove that it terminates in a finite number of steps with probability 1. O.C. and A.S.N. functions. Examples of (i) Binomial (ii) Normal cases for testing hypothesis μ and σ^2 .

UNIT-IV: Notion of Non-Parametric test, Different N-P tests; Run test, Sign test, Wilcoxon and Mann-Whitney test, Median test; Derivation of the mean and variance of the above test statistics when null hypothesis is true.

UNIT-V: χ^2 – test for goodness of fit, its asymptotic distribution, description of Kolmogorov-Smirnov test, Tests involving Rank correlation (Kendall's Tau and Spearman's rank Correlation).

Text Books:

Rohatgi, V.K (1984): Statistical Inference, John Wiley & Sons.

Gibbons, J.D and Chakraborti, S (2003): Non-Parametric Inference, McGraw Hill, 4th Ed. Marcel-Dekkar Inc.

Wald (1973): Sequential Analysis, Dover, New York.

Goon, Gupta and Das Gupta: An Outline Statistical Theory, Vol.2, The World Press Pvt. Ltd., Calcutta.

Reference Books:

Lehmann, E.L (1983): Testing of Statistical Hypothesis, John Wiley & Sons.

Rao, C.R. (1972): Linear Statistical Inference and its Applications, 2nd Ed, John Wiley & Sons.

Sidney Siegel (1956): Non Parametric Statistics for the Behavioral Sciences, McGraw Hill, Tokyo.

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Paper – 2.3: STOCHASTIC PROCESSES

Course Outcomes:

- CO1: Understand the meaning of stochastic process along with classification of stochastic processes, Fine state Markov chains, classification of states of a Markov chain, limiting and stationary distribution of a Markov chain.
- CO2: Understand random walk processes in one- and two-dimensions, random walk processes with and without barriers, identifying Markov chains associated with random walk, and their application to gambler's ruin problem.
- CO3: Understand homogeneous Poisson process, nonhomogeneous Poisson process, compound Poisson process and important properties of these processes, pure birth process, pure death process, general birth-death process.
- CO4: Understand Galton-Watson branching process and associated generating functions and their relations, probability of ultimate extinction of a branching process. Wiener process as a limiting case of random walk process and elementary properties of the Wiener process.
- CO5: Understand renewal process, elementary renewal theorem, residual and excess lifetime distributions. Understand weak-sense stationary and strict-sense stationary processes.

Course Specific Outcomes:

- CSO1: Able to identify the nature of the time parameter and state space as well as dependence structure among the process variables of a stochastic processes.
- CSO2: Able to understand the properties and applications of discrete time stochastic processes like Markov chains, branching process and random walk processes.
- CSO3: Able to understand the properties and applications of continuous time stochastic processes like Poisson process, Wiener process and renewal process.

Learning Outcomes:

- LO1: Understand the definition of a stochastic process, classification of stochastic processes, and classification of states of a stochastic process.
- LO2: Understand restricted and unrestricted random walk processes and their application in solving problems relating to gambler ruin.
- LO3: Understand the discrete and continuous time Markov chains, stationary and limiting distribution of Markov chains, Poisson process and its generalizations and their applications.
- LO4: Understand the definition and properties of Wiener process as well as branching process and their applications.

LO5: Understand different types of stationary processes, renewal theory, its properties and applications.

UNIT-I: Introduction to Stochastic processes; classification of Stochastic processes according to state space and time domain. Countable state Markov chains (MC's), Chapman Kolmogorov equations; calculation of n-step transition probability and its limit. Classification of states, period of a state. Stationary distribution of MC.

UNIT-II: Random walk and gambler's ruin problem; Random walk in one and two dimensions. Gambler's ruin problem, probability of ultimate ruin, expected duration of the game.

UNIT-III: Discrete state space continuous time MC: Poisson process and its properties, birth process, death process and birth and death process.

UNIT-IV: Wiener process as a limit of random walk and some elementary properties of Wiener process. Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size.

UNIT-V: Renewal theory: Elementary renewal theorem and applications. Study of residual and excess life times and their distributions. Stationary process: weakly stationary and strongly stationary processes.

Text Books:

Medhi J. (1994): Stochastic Processes. 2nd Ed, New Age, New Delhi

Bhat, B.R. (2000): Stochastic Models: Analysis and Applications, New Age International India

Basu. A.K. (2003): Introduction to Stochastic Process, Narosa Publishing House, Chennai.

Srinivasan S.K and Mehta K.M (1981): Stochastic Process

Reference Books:

Adke, S.R. and Manjunath, S.M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.

Cinlar, E. (1975): Introduction to Stochastic Processes, Prentice Hall.

Feller, W. (1968): Introduction to Probability and its Applications, Vol. 1, Wiley Eastern

Hoel, P.G., Port, S.C. and Stone, C.J (1972): Introduction to Stochastic Process, Houghton Mifflin and Co.

Karlin, S. and Taylor, H.M. (1975): A First Course in Stochastic Processes, Vol. 1.

Parzen, E. (1962): Stochastic Processes, Holden Day.

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Paper-2.4: DESIGN AND ANALYSIS OF EXPERIMENTS

Course Outcomes:

- CO1: Able to understand ANOVA, ANCOVA, fixed and random effect models.
- CO2: Able to understand the concepts of CRD, RBD, LSD and their missing plot techniques.
- CO3: Can construct the multiple comparison tests and split plot design.
- CO4: Can summarize the analysis of 2^n and 3^2 factorial designs and able to test their significance.
- CO5: Familiarize with total and partial confounding.
- CO6: Understand how to perform experiment using Youden square design. Can construct BIBD and PBIBD and can perform their analysis.

Course Specific Outcomes:

- CSO1: Able to identify model adequacy checking using Bartlett test and Modified Levene method.
- CSO2: Able to apply missing plots techniques in RBD and LSD.
- CSO3: Acquainted with the analysis of 2^n and 3^2 factorial designs and total and partial confounded designs.

Learning Outcomes:

- LO1: Acquire theoretical foundations for design and analysis of experiments.
- LO2: Able to apply ANCOVA technique.
- LO2: Expertized in analysis of experiments and perform the data analysis using CRD, RBD and LSD even in case of missing values.
- LO3: Capable of testing the model adequacy.
- LO4: Expertize in analyzing factorial designs and estimate factorial effects and test their significance. Experiment confounding techniques to real life problems.
- LO5: Able to apply the Youden square design and intra block analysis for estimating the Parameters of BIBD and PBIBD.
- LO6: Expertized in applying different analysis of variance techniques in agricultural business and industries.

UNIT-I: Principles of designs, analysis of variance and analysis of co-variance, fixed and random effect models. Contrasts. Model Adequacy checking: Test for Normality, Test for equality of Variances (Bartlett test, Modified Levene method)

UNIT-II: C.R.D., R.B.D., Estimation of parametric functions and tests of hypothesis. Comparison of their efficiencies. Missing plot techniques, testing the equality of subsets of block effects or treatment effects. Multiple comparisons tests: Tukey's test, The Fisher Least significant Difference (LSD) method, Duncan's Multiple range test.

UNIT-III: L.S.D., Orthogonality in L.S.D., Missing plot technique, Analysis of split plot design.

UNIT-IV: Factorial Designs: Analysis of 2^n and 3^2 designs. Estimation of factorial effects. Testing their significance, Total and Partial confounding.

UNIT-V: Youden Square design, intra block analysis. B.I.B.D., P.B.I.B.D., their analysis - estimation of parameters, tests of hypothesis.

Text Books:

Das. M.N. and Giri, N.C.: Design and Analysis of Experiments, New Age International (P) Ltd.
Montgomery, D.C.: Design and Analysis of Experiments, John Wiley and Sons, New York.

Reference Books:

Cochran and Cox: Experimental Designs, Asia Publishing House, Bombay.
Oscar Kempthorne (1975): The Design and Analysis of Experiments, Wiley – Eastern Pvt. Ltd, New Delhi.

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Paper – 3.1: OPERATIONS RESEARCH – I

Course Outcomes:

- CO1: Able to acquire knowledge of scope of Operations Research.
- CO2: Able to formulate LPP and to solve problems using graphical, simplex and revised simplex methods.
- CO3: Able to solve transportation, assignment, sequencing and scheduling problems.
- CO4: Able to deal with inventories of various goods with and without shortages.
- CO5: Able to derive steady state solutions of Poisson queues.
- CO6: To acquaint with non-Poisson queues.

Course Specific Outcomes:

- CSO1: To acquire knowledge of Operations Research.
- CSO2: To distinguish simplex and duality methods.
- CSO3: To identify transportation and assignment problems as particular case of LPP.
- CSO4: To be able to maintain inventories of various goods with and without shortages.

Learning Outcomes:

- LO1: Understand optimization through LPP.
- LO2: To provide the idea of formulating mathematical model and their optimum solution in the contest of practical problems belonging to Government /Private sectors.
- LO3: Understand and deal with Poisson and non-Poisson queuing problems.
- LO4: Acquire knowledge of OR that will be useful in professional life.
- LO5: Obtain a firm foundation in advanced OR techniques for the real life problems.

UNIT-I: Definition and scope of Operational research. Phases in Operations Research. Models and their solutions. Linear Programming: Graphical, Simplex, Revised simplex methods. Duality, sensitivity analysis.

UNIT-II: Transportation and assignment problems. Sequencing and scheduling problems: 2 machine n-job and 3- machine n-job problems with identical machine sequence for all jobs; 2- job n-machine problem with different routings.

UNIT-III: Analytical structure of inventory problem: EOQ formula of Harris, its sensitivity analysis and extensions allowing quantity discounts and shortages. Multi-item inventory subject to constraints. Models with random demand, the static risk model, P and Q- systems with constant and random lead times.

UNIT-IV: S-s policy for inventory and its derivation in the case of exponential demand; multi-echelon inventory models. Queuing models: specifications and effectiveness measures. Steady-state solutions of M/M/1 and M/M/C models with associated distributions of queue length and waiting time.

UNIT-V: M/G/1 queue and Pollazcek- Khinchine result. Steady-state solutions of $M/E_k/1$ and $E_k/M/1$ queues. Machine interference problem. Bulk queues (bulk arrival and bulk service); finite queues; queues in tandem; GI/G/1 queue and its solution; simulation of queues.

Text Books:

Kanti Swarup, Gupta, P.K and Man Mohan (1985): Operation Research; Sultan Chand and Sons
J.K. Sharma (2003): Operation Research Theory and Applications; Macmillan India
S.D. Sharma: Operations Research. Kedarnath Ramnath Publishers. Meerut.

Reference Books:

Taha H.A (1982): Operational Research: An Introduction; Macmillan.
Hillier F.S. and Leiberaman G.J. (1962): Introduction to Operations Research; Holden Day.
Churchman C.W., Ackoff R.L. and Amoff E.L. (1957): Introduction to Operations Research, John Wiley.
Gross, D. and Harris, C.M. (1974): Fundamentals of Queuing Theory, John Wiley.

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Paper - 3.2: LINEAR MODELS AND REGRESSION ANALYSIS

Course Outcomes:

- CO1: Able to calculate least square estimates of Gauss-Markov model.
- CO2: Able to obtain estimates in case of correlated observations.
- CO3: Able to test hypothesis for linear parametric functions.
- CO4: To be able to deal with multiple regression analysis.
- CO5: Able to estimate regression coefficient under multicollinearity.

Course Specific Outcomes:

- CSO1: To acquire knowledge of variances and covariances of least square estimates under Gauss-Markov setup.
- CSO2: Able to estimate error variance under Gauss-Markov setup.
- CSO3: Able to estimate the parameters when they are subject to linear restrictions and correlated observations.
- CSO4: To perform Analysis of Variance and to construct confidence intervals and regions.
- CSO5: Able to fit polynomial models and know the usage of orthogonal polynomial models.

Learning Outcomes:

- LO1: Able to get theoretical foundation for linear estimation theory and regression analysis.
- LO2: Able to demonstrate the least square estimates of the parameters and their statistical significance.
- LO3: Acquainted with different regression techniques that can be used in statistical analysis.
- LO4: Expertise with different methods for estimating and testing the relationships between independent and dependent variables.

Unit I: Gauss-Markov set-up, Normal equations and Least squares estimates, variances and covariances of least squares estimates, estimation of error variance.

Unit II: Estimation with correlated observations, least squares estimates with restriction on parameters, simultaneous estimates of linear parametric functions.

Unit III: Tests of hypotheses for one and more than one linear parametric functions, confidence intervals and regions. Analysis of Variance.

Unit IV: Simple linear regression, multiple regression, fit of polynomials and use of orthogonal polynomials.

Unit V: Multicollinearity, Ridge regression and principal component regression, subset selection of explanatory variables.

Text Books:

Graybill, F.A.(1983): Matrices with Applications in Statistics. Wadsworth.

Draper, N.R. and Smith, H (1998): Applied Regression Analysis. 3rd Edition. Wiley-Blackwell.

Douglas C. Montgomery, Elizabeth A. Peck and G. Geoffrey Vining (2012): Introduction to Linear Regression Analysis – 5th Edition. Wiley

Goon, Gupta and Das Gupta (2003): An outline of Statistical Theory. Volume II. The World Press Pvt. Ltd.

Reference Books:

Bapat.R.B. (2012): Linear Algebra and Linear Models. 3rd Edition. Springer.

Cook, R.D. and Weisberg, S. (1983): Residual and Influence in Regression. 1st Edition. Chapman and Hall.

Johnson, J. (1996): Econometric Methods, 4th Edition. McGraw Hill.

Rao, C.R. (2002): Linear Statistical Inference and Its Applications. 2nd Edition. Wiley-Blackwell.

Weisberg, S. (2013): Applied Linear Regression. 4th Edition. Wiley.

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Optional Paper (a): DEMOGRAPHY

Course Outcomes:

- CO1: Understand census in India: pre independence and post-independence era. Also able to distinguish Whipple, Myer and UN indices.
- CO2: Can summarize various measures of fertility and also sketch the uses of stochastic reproduction models.
- CO3: Able to construct various measures of mortality and able to construct abridged life tables.
- CO4: Can classify stable, quasi-stable population and calculate intrinsic growth rate. Also able to predict population projection with different methods.
- CO5: Able to choose different models for calculating population growth and their fitting to population data. Acquaint with stochastic models for population growth.

Course Specific Outcomes:

- CSO1: Aware of population census of India. Able to identify coverage and content errors in demographic data and also identify the distinguish between Whipple, Myer and UN indices in terms of adjustment of age data.
- CSO2: Able to sketch measures of fertility and mortality and construct abridged life tables.
- CSO3: Able to estimate population growth and familiar with different methods for population projection.
- CSO4: Able to apply different models of population growth and stochastic models for population data.

Learning Outcomes:

- LO1: Student able to identify the coverage and content errors in demographic data.
- LO2: Expertized in construction of various measures of fertility, mortality and stochastic models for reproduction.
- LO3: Expertize in applying different methods for population projections.
- LO4: Able to fit different population growth models and can apply stochastic models for given population data.

UNIT-I: Scope and content of population census of India. Population, Composition, Dependency ratio. Brief Coverage and content errors in demographic data. Adjustment of age data – use of Whipple, Myer and UN indices. Chandrasekhar – Deming formula to check completeness of registration data.

UNIT-II: Measures of fertility: Stochastic models for reproduction, (Dandekar's Modified Binomial and Poisson distributions, William Brass Model), distributions of time to first birth, inter-live birth intervals and number of births.

UNIT-III: Measures of Mortality: Construction of abridged life tables (l_x -linear, exponential, Reed and Merrell's, Grevill's) Relations between functions of Life Tables. Distributions of life table functions.

UNIT-IV: Stable and quasi-stable populations, intrinsic growth rate. Methods for population projection. Use of Leslie matrix.

UNIT-V: Models for population growth and their fitting to population data. Linear, Exponential, logarithmic, modified logarithmic, Gompertz and Logistic Curves. Stochastic models for population growth (Pure Birth Model, Simple Birth & Death Model, Birth, death and migration model).

Text Books:

Sudhendra Biswas (1995): Applied Stochastic Processes, New Age International Publishers Ltd.

Pathak, K.B. & Ram, F. (1998): Techniques of Demographic Analysis, Himalaya Publishing House.

K.Srinivisan (1998): Basic Demographic Techniques and Applications: Sage publications.

Asha A Bhande, Tara Kanitkar (2004): Principles of Population Studies; Himalaya Publishing House.

Reference Books:

Saxena H.C and Surrendran P.U: Statistical Inference.

Bartholomew, D.J.(1982): Stochastic Models for Social Processes, John Wiley.

Benjamin, B. (1969): Demographic Analysis, George Allen and Unwin Ltd.

Chain, C.L (1968): Introduction to Stochastic Processes in Biostatistics; John Wiley.

Cox, P.R. (1970): Applied Mathematical Demography, Springer Verlag.

Spiegelman, M. (1969): Introduction to Demographic Analysis; Harvard University Press.

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Optional Paper (b): INDUSTRIAL STATISTICS AND QUALITY CONTROL

Course Outcomes:

- CO1: Able to understand basics of production process monitoring and apply concept of control charts to it.
- CO2: Apply acceptance and continuous sampling plan in production process.
- CO3: Able to construct sampling inspection plans for attributes and variables.
- CO4: Able to learn some advanced control charts and capability indices.
- CO5: Able to construct Six Sigma limits.

Course Specific Outcomes:

- CSO1: Acquaintance with statistical quality control techniques such as control charts, acceptance sampling plans, continuous sampling plans.
- CSO2: Able to analyse the industrial data about specific perception.
- CSO3: Calculate capability indices.
- CSO4: Able to relate process improvement and product development.
- CSO5: Able to implement response surface methodology in quality control.

Learning Outcomes:

- LO1: Can identify the cause of defects using statistical quality management techniques.
- LO2: Able to apply statistical quality control techniques to minimise the variability in manufacturing and business process.
- LO3: Acquainted with Six Sigma and lean thinking in industrial experimentation.
- LO4: Expertise in the most import field of applied statistics that contributes to quality control in all most all industries.

UNIT-I: General Theory of Control Charts: Control charts for attribute and variables: O.C. and A.R.L. of control charts; control by gauging; Moving average and exponentially weighted moving average charts;

UNIT-II: Cu-sum charts using V-masks and decision intervals. Capability indices: Cp, Cpk and Cpm.

UNIT-III: Acceptance sampling plans for attribute inspection: Single, double and sequential sampling plans; Plans for inspection by variables for one-sided and two-sided specifications;

UNIT-IV: Mil Std and ISI plans; Continuous sampling plans of Dodge type and Wald-Wolfwitz type and their properties.

UNIT-V: Industrial Experimentation, Fractional factorial experiments, Response surface methodology, Six sigma in process improvement and product development, Lean thinking, Value stream analysis, 5 s.

Text Books:

Cowden D J (1957): Statistical Methods in Quality Control. 1st Edition. Prentice-Hall Inc.

Duncan Acheson (1986): Quality Control and Industrial Statistics. 5th Edition. Irvin

Mittag and Rinne (1993): Statistical Methods for Quality Assurance. 2nd Edition. Chapman and Hall Ltd.

Montgomery. D.C (2012): Introduction to Statistical Quality Control. 7th Edition. John Wiley and Sons

R.C. Gupta (2001): Statistical Quality Control. 9th Edition. Khanna Publishers.

Reference Books:

Ott, E.R. (1975): Process Quality Control. 4th Edition. Mc Graw Hill

Phadke, M.S. (1989): Quality Engineering through Robust Design. 1st Edition. Prentice Hall

Wetherill, G.B. (1977): Sampling Inspection and Quality Control. 2nd Edition. Chapman and Hall Ltd.

Wetherill, G.B. and Brown, D.W. (1991): Statistical Process Control. Theory and Practice. 3rd Edition. Chapman & Hall Ltd.

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Optional Paper (c): TIME SERIES ANALYSIS

Course Outcomes:

- CO 1:** To demonstrate advanced understanding of the concepts of time series analysis and their applications.
- CO 2:** To demonstrate decomposition of time series tests for trend and seasonality.
- CO 3:** To understand the various methods of smoothing and analysis of time series data.
- CO 4:** To understand the analysis of stationary models in time series.
- CO 5:** To develop stationary and non stationary models and their diagnostic check.
- CO 6:** To acquire scientific knowledge for forecasting and applying it to various sectors.

Course Specific Outcomes:

- CSO 1:** The students are trained to get cutting edge of knowledge in time series analysis and applications.
- CSO 2:** Can demonstrate skills and knowledge in communicating statistical techniques for scientific data analysis.
- CSO 3:** To acquire the basic require knowledge to do research and to take up advanced studies in time series analysis.
- CSO 4:** To develop teamwork and sharing knowledge with others including non statisticians for time series analysis.
- CSO 5:** To construct and design mathematical and computer models for conducting time series analysis of any phenomenon.

Learning Outcomes:

- LO 1:** Able to understand and analyse components of time series.
- LO 2:** Able to explain time series with different structures.
- LO 3:** Able to perform trend analysis, develop seasonal indices, analysis cyclical variations and random components.
- LO 4:** Able to smooth the data and apply various smoothing methods for data analysis.
- LO 5:** Able to construct time series models and analyse.
- LO 6:** Able to able to forecast with different scientific methods.
- LO 7:** Able to become an expert in time series analysis and applications.

UNIT-I: Time-series as discrete parameter stochastic process. Autocovariance and autocorrelation functions and their properties. Exploratory Time Series Analysis, Tests for trend.

UNIT-II: Exponential and Moving Average Smoothing. Holt and Winters' smoothing. Forecasting based on smoothing, Adaptive smoothing.

UNIT-III: Detailed study of the stationary process: Moving Average (MA), Auto Regressive (AR), ARMA and AR Integrated MA (ARIMA) models.

UNIT-IV: Box – Jenkins models. Discussion (without proof) of estimation of mean, autocovariance and autocorrelation functions under large sample theory. Choice of AR and MA periods. Estimation of ARIMA model parameters. Forecasting. Residual analysis and diagnostic checking.

UNIT-V: Spectral analysis of weakly stationary process. Periodogram and correlogram analysis. Computations based on Fourier transform.

Text Books:

Box, G.E.P. and Jenkins, G.M. (1976): Time Series Analysis –Forecasting and Control. Holden Day, San Francisco.

Anderson, T.W. (1971): The Statistical Analysis of Time Series, Wiley, New York.

Makridakis, Wheelwright and McGee: Forecasting - Methods and Applications, John Willey and Sons.

Montgomery, D.C. and Johnson, L.A. (1977): Forecasting and Time Series Analysis, McGraw Hill

Reference Books:

Fuller, W.A. (1976): Introduction to Statistical Time Series, John Wiley

N.V. Granger, C.W.J. and Newbold (1984): Forecasting Econometric Time Series, 3rd Edition, Academic Press.

Priestley, M.B. (1981): Spectral Analysis and Time Series, Griffin, London.

Kendall, Sir Maurice and Ord, J.K. (1990): Time Series Analysis. 3rd edition Edward

Kendall, M.G. and Stuart A. (1966): The Advanced Theory of Statistics, Volume 3, Charles Griffin. London

Bloomfield, P. (1976): Fourier Analysis of Time Series – An Introduction, Wiley. Granger,

Granger, C.W.J. and Hatanka, M. (1964): Spectral Analysis of Economic Time Series, Princeton Univ. Press. New Jersey.

Koopmans, L.H. (1974): The Spectral Analysis of Time Series, Academic Press.

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Optional Paper (d): COMPUTER INTENSIVE STATISTICAL METHODS

Course Outcomes:

- CO1: Understand different methods of generating random samples from univariate and multivariate probability distributions.
- CO2: Understand Monte Carlo integration of approximating integrals and different methods of variance reduction of Monte Carlo estimates of variance reduction.
- CO3: Understand algorithms such as Gibbs and Metropolis-Hastings and their applications and simulation methods for solving hypothesis testing problems.
- CO4: Learn bootstrap methods for estimating bias and standard error of estimators, and bootstrapping for constructing confidence intervals for parameters.
- CO5: Understand jackknife method for estimating bias and standard error of an estimator and its use in estimating variances of the estimators in complex sample surveys.

Course Specific Outcomes:

- CSO1: Able to simulate samples from univariate and multivariate distributions.
- CSO2: Able to apply Monte Carlo methods to approximate complex integration problems.
- CSO3: Able to use resampling methods to solve statistical inference problems.

Learning Outcomes:

- LO1: Student should be able to generate random samples from univariate and multivariate distributions.
- LO2: Student should be able to apply Monte Carlo integration to various integration problems that naturally arise in statistics.
- LO3: Student can apply the MCMC methods for multivariate simulation. He/she is expected to solve statistical inference problems using Monte Carlo methods.
- LO4: Student should be able to apply resampling methods to find approximations to sampling distributions and construct approximate confidence intervals for parameters of interest.
- LO5: Student should be able to apply the jackknife technique for estimation of variances in sample surveys.

UNIT-I: Stochastic simulation - generating univariate random variables using Inverse Transform Method, Composition Method, Convolution Method, Accept/Reject Method and Particular Methods. Generating bivariate/multivariate normal random vectors using Transformation Method and Conditional Distribution Method. Bartlett's Decomposition Method for generating Wishart matrices.

UNIT-II: One Dimensional and Multidimensional Monte Carlo Integration - Variance reduction techniques for Monte Carlo integration using Antithetic variates method, Control variate Method, Conditional Monte Carlo method and Importance Sampling for integration - Maximum Principle and Tilted Sampling

UNIT-III: Markov Chain Monte Carlo methods - Gibbs sampling for bivariate/multivariate simulation, Metropolis Algorithm, Metropolis-Hastings Algorithm. Random walk Chains, Independence Chains. Simulation based hypothesis testing - simulating test statistics and power functions, Permutation Tests, Bootstrap Tests.

UNIT-IV: Bootstrap methods: re-sampling paradigms, bias and standard errors, confidence intervals - Basic confidence intervals, Standard confidence intervals, bootstrap-t confidence intervals, and Percentile confidence intervals. Bootstrapping in regression - Bootstrapping cases, and Bootstrapping Residuals.

UNIT-V: Introduction to Jackknife, jackknife bias estimate, jackknife standard error estimate, jackknife in sample surveys, jackknife for variance estimation, jackknife repeated replication, delete-a-group jackknife, Cross-validation for tuning parameters.

Text Books:

R. Rubinstein (1981) Simulation and the Monte Carlo Method. Wiley.

M.A. Tanner (1996): Tools for Statistical Inference, Third Edition. Springer.

B. Efron and R.J. Tibshirani (1993) An Introduction to the Bootstrap. Chapman and Hall.

Jun Shao and D.Tu (1995) The Jackknife and the Bootstrap. Springer Verlag.

A.C. Davison and D.V. Hinkley (1997) Bootstrapping Methods and their Applications, Cambridge University Press.

G.S. Fishman (1996) Monte Carlo: Concepts, Algorithms, and Applications. Springer.

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Optional Paper (e): MACHINE LEARNING

Course Outcomes:

- CO1: Able to understand the concept of learning.
- CO2: Expertise in classification techniques.
- CO3: To be able to explore perception learning.
- CO4: Able to understand decision tree classification.
- CO5: Able to understand the concept of clustering.
- CO6: To acquaint with Gaussian mixture models

Course Specific Outcomes:

- CSO1: Able to get thorough understanding of classification and clustering techniques.
- CSO2: Can analyse the data by applying parameter estimation method to data sets.
- CSO3: Distinguish different classification evaluation measures on the data sets.
- CSO4: Able to perform multi-classification.
- CSO5: Apply SVM and ANN for discussing the validation of data sets.
- CSO6: Able to understand reinforcement learning.

Learning Outcomes:

- LO1: For analysing real world data student is able to select different machine learning algorithms.
- LO2: Able to experiment classification with decision tree.
- LO3: Able to construct graphical models for clustering.
- LO4: Able to perform model based clustering.
- LO5: Develop basic knowledge to pursue research in machine learning.

UNIT-I: Introduction to Machine Learning: Supervised learning, Unsupervised learning, Reinforcement learning.

Statistical Decision Theory – Regression, Classification, Bias - Variance, Linear Regression, Multivariate Regression. Subset selection. Logistic Regression, Linear Discriminant Analysis.

UNIT-II: Perception Learning: SVM Formulation, SVM Interpolation and Analysis, SVMs for Linearly Non Separable data, SVM kernals. ANN: Early Methods: Back Propagation, Initialization, Training and Validation, Parameter Estimation: Parameter Estimation – MLE, Priors, Bayesian Estimation.

UNIT-III: Decision Trees: Introduction, Regression Trees, Stopping Criteria, Pruning, Decision Trees for classification – Loss function, Categorical attributes, Multiway Splits, Missing values, Impulation and Surrogate splits, Instability, Smoothness, Repeated subtrees, Evaluation measures – Bootstrapping and cross validation, Class evaluation measures, ROC Curve.

UNIT-IV: Bayesian Networks: Undirected graphical models - Introduction, Potential functions, Hidden Markov Models - Variable elimination, Belief propagation, Multiclass classification. Partitional clustering – Hierarchical clustering.

UNIT-V: Gaussian Mixture Models, Expectation Maximization, algorithm, model based clustering, Frequent item set mining. Learning Theory: Introduction to Reinforcement Learning, R L frame work, T D learning, Solutions methods and applications.

Text Books:

1. Tom M. Mitchell (2013), Machine Learning, Mc Graw Hill Education (India) Pvt. Limited.
2. Ethem, Alpaydin (2012), Introduction to Machine Learning, 2nd ed., PHI Learning Private Limited, New Delhi.

Reference Books:

1. Jared Dean (2014), Big Data, Data Mining and Machine Learning, Wiley.
2. Peter Harrington (2015), Machine Learning in Action, Dream tech Press.

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Paper – 4.1: OPERATIONS RESEARCH –II

Course Outcomes:

- CO1: Able to apply decision theory when the probabilities of occurrence of various states of nature are not known.
- CO2: Can apply Game theory to analyze existing situations wherever there are limited resources, different decision options and different outcomes from different choices.
- CO3: Use dynamic programming in multistage solution problems.
- CO4: Able to find optimum solution by applying different IPP algorithms when the variables are restricted to be integers.
- CO5: Using PERT and CPM able to find the minimum time required to complete project when it involves interdependent activities.
- CO6: Able to understand and deal with non-linear real life problems and quadratic programming problems.

Course Specific Outcomes:

- CSO1: To acquire knowledge of Operations Research.
- CSO2: Arrive solution to the given problem using decision tree analysis.
- CSO3: Able to apply game theory as a tool to analyze economic competition.
- CSO4: Able to speed up project's completion time using the concept of crashing.
- CSO5: Can compare accuracy, completeness, consistency, uniqueness, and timeliness of different codes using information theory.

Learning Outcomes:

- LO1: Acquainted with the use of optimization techniques in decision making.
- LO2: Able to analyze existing situations wherever there are limited resources, different decision options, different outcomes from different choices.
- LO3: Acquainted with ideas of formulating mathematical modelling and their optimum solution in the contest of practical problems belonging to Government /Private sectors.
- LO4: Obtain optimum solutions for real life problems using integer programming.
- LO5: Expertize in finding ways to make more efficient codes in digital processing by applying Information theory.
- LO6: Obtain a firm foundation in advanced OR techniques for the real life problems.

UNIT-I: Decision Theory: Decision theory approach, Decision theory under uncertainty, under risk, posterior probabilities and Bayesian analysis, Decision tree analysis, Decision making with utilities.

UNIT-II: Game Theory: Two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in $n \times 2$, $2 \times m$ and $m \times n$ games. Dynamic Programming.

UNIT-III: Integer programming-branch and bound algorithm and cutting plane algorithm. Multi-criterion and goal programming. Replacement problems; block and age

UNIT-IV: Project management; PERT and CPM; probability of project completion, crashing.

UNIT-V: Information Theory: Communication Process, Entropy, Channel capacity, Efficiency, Redundancy, Shannon-Fano encoding procedures. Non-linear programming: Kuhn Tucker conditions, Wolfe and Beadle's algorithms for solving quadratic programming problems.

Text Books:

Kanti Swarup, Gupta, P.K and Man Mohan (2000): Operations Research; Sultan Chand & Sons
J.K. Sharma (2003): Operations Research- Theory and Applications; Mac Millan, India
S.D. Sharma: Operations Research, Kedar Nath Ram Nath Publishers. Meerut.

Reference Books:

Taha H.A. (1982): Operational Research - An Introduction; 10th edition, Pearson.
Hillier F.S. and Lieberman G.J. (1962): Introduction to Operations Research, Holden Day.
Churchman C.W., Ackoff, R.L. and Arnoff, E.L. (1957): Introduction to Operations Research, John Wiley.
Gross, D. and Harris, C.M. (1974): Fundamentals of Queuing Theory, John Wiley.

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PAPER – 4.2: COMPUTER PROGRAMMING – C++

Course Outcomes:

- CO1: Understand principles of object oriented programming, defining classes, creating objects, initializing objects and destroying objects.
- CO2: Understand friend functions, inline functions, single and multiple inheritance, different types of derivation and ambiguity in inheritance.
- CO3: Understand virtual base class and container classes. Learn to overload functions and operators.
- CO4: Understand polymorphism, virtual functions, pure virtual functions, constructors and destructors under inheritance.
- CO5 Understand templates, exception handling, use of data files.

Course Specific Outcomes:

- CSO1: Able to understand object-oriented concepts such as data abstraction, encapsulation, inheritance, dynamic binding, and polymorphism.
- CSO2: To understand the syntax of C++ and writing simple programs using OOP concepts in C++.
- CSO3: Get familiarized with templates, file processing and exception handling in C++.

Learning Outcomes:

- LO1: Understand principles of object-oriented programming, classes, different types of constructors and destructors.
- LO2: Understand friend functions, different types of inheritance and their use.
- LO3: Understand function overloading and operator overloading, overloading of unary and binary operators.
- LO4: Understand the definitions of abstract base classes, similarities and differences of virtual functions, and their use in polymorphism.
- LO5: Understand the utility of function templates and class templates, exception handling mechanisms and use of data files.

UNIT-I: Object oriented programming principles, Declaration of classes, array of classes, Pointer to classes, constructors such as void constructor, copy constructor, Destructor,

UNIT-II: Friend functions, inline functions, static class members, this pointer, Single, Multiple inheritances: Types of derivation such as public, private, protected inheritance and member access controls, ambiguity in inheritance,

UNIT-III: Virtual base class, container classes. Function overloading, Operator Overloading, Overloading of assignment, binary, unary operators.

UNIT-IV: Polymorphism, Early binding, virtual functions, Late binding, pure virtual functions, abstract base classes, constructor under inheritance, destructor under inheritance, virtual destructors.

UNIT-V: Templates and Exception Handling. Data File operations, structures and file operations, classes and file operations.

Text Books:

Deital & Deital: C++; Prentice-Hall Inc.

Sarang: Object Oriented programming with C++; Prentice-Hall Inc.

Balaguruswamy, E : Programming with C++; Tata McGraw-Hill.

Reference Books:

R.Decker and So Hirshfield (1998): The Object Concept: An Introduction to Computer Programming using C++; PWS Publishing.

S.B.Lippmann and J.Lajoie (1998): C++ Primer. Third edition. Addison- Wesley. P.Nauahton (1996). The Java Handbook. Tata McGraw-Hill

W.J. Savitch (2001): Problem Solving with C++ The Object of Programming. Third Edition. Addison-Wesley Longman.

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Optional Paper (a): ECONOMETRICS

Course Outcomes:

- CO1: Able to summarize nature and scope of econometrics and apply OLS estimation of the general linear model for real life problems.
- CO2: Can test structural changes of the model and the equality of two regressions equations.
- CO3: Identify heteroscedasticity using Goldfield-Quandt, Park and weighted least squares methods.
- CO4: Classify the distributed lag models and identify the errors in variables.
- CO5: Distinguish different forms of simultaneous equations models by order and rank conditions.

Course Specific Outcomes:

- CSO1: Able to evaluate OLS estimators under linear restrictions.
- CSO2: Able to construct Aitken estimator for generalized linear models.
- CSO2: Able to use dummy variables for seasonal adjustments.
- CSO3: Able to use various methods to test heteroscedasticity in the given data.
- CSO4: Detect and estimate autocorrelation using Durbin-Watson statistic.

Learning Outcomes:

- LO1: Expertize in estimation and testing of hypothesis in econometric models.
- LO2: Can judge structural changes and perform seasonal adjustments using dummy variables.
- LO3: Able to estimate distributed lag models using Koyck approach, Adaptive expectation model and stock adjustment model.
- LO4: Acquaint with ILS, 2SLS, IV, LIML and 3SLS methods of estimation..
- LO5: Acquire knowledge in econometric techniques, various functions for economic analysis and future forecasting which are useful in business, finance and many other disciplines.

UNIT-I: Nature and scope of Econometrics. General linear model: Assumptions, O.L.S method of estimation, Tests of hypothesis, Confidence intervals, Prediction, Estimation subject to linear restrictions, Maximum Likelihood estimator.

UNIT-II: Tests of structural change; Dummy variables and seasonal adjustments, Equality of two regressions equations, Specification errors; Estimation methods.

UNIT-III: Generalized Least squares: Aitken estimators, Heteroskedasticity: Goldfield – Quandt test, Park test, Weighted least square method of estimation. Autocorrelation: Detection

by Durbin- Watson statistic, Estimation methods (Cochran Orcutt and Durbin's methods of estimation) SUR system of equations.

UNIT-IV: Lagged Variables: Distributed lag models: Koyck approach, Adaptive Expectations Model, Stock Adjustments Models, Almon's approach. Errors in Variables.

UNIT-V: Simultaneous Equation Models: Structural form, Reduced form and recursive form, Identification Problems, Order and Rank conditions, Methods of Estimation: ILS, 2SLS, IV, LIML and 3SLS.

Text Books:

Gujarathi, D(1979): Basic Econometrics, McGraw Hill.

Johnston. J. (1984): Econometric methods, Third edition, McGraw Hill

Koutsoyiannis, A (1979): Theory of Econometrics, Macmillan Press

Theil. H (1982): Introduction to the Theory and Practice of Econometrics, John Wiley.

Reference Books:

Apte P.G. (1990): Textbook of Econometrics. Tate McGraw Hill

Cramer. J.S. (1971): Empirical Econometrics. North Holland.

Intrilligator, M.D. (1980): Econometric models – Techniques and Applications, Prentice Hall of India.

Klein, L.R.(1962): An introduction to Econometrics, Prentice Hall of India

Mai Invaud, E (1966): Statistical Methods of Econometrics, North Holland

Srivastava, V.K. and. Giles D.A.E (1987): Seemingly Unrelated Regression Equation Models, Marcel Dekker.

Walters, A (1970): An Introduction to Econometrics. McMillan & Go,

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Optional Paper (b): ACTUARIAL STATISTICS

Course Outcomes:

- CO1: Able to learn the concept of interest, different terminologies like loss function, net premium and life annuities.
- CO2: Able to understand the utility and insurance theory and life tables.
- CO3: To understand the concept of life insurance and the existing insurance products of different insurance companies.
- CO4: Able to learn the concepts of death - level benefit insurance, endowment insurance, deferred insurance, varying benefit insurance, claim amount distribution.
- CO5: Able to acquire knowledge different life functions.

Course Specific Outcomes:

- CSO1: Able to understand the concept of life insurance and existing products of different insurance companies.
- CSO2: Enrich about the awareness about the status of health and life insurance.
- CSO3: To learn about the associated business through insurance policies.
- CSO4: To apply mathematical and statistical methods to assess risk in the insurance and finance industries.

Learning Outcomes:

- LO1: Learn the mechanisms of life and health insurance.
- LO2: Get expertise in the probability models that can be designed for aggregate values of population survival.
- LO3: When uncertainty involved, student can develop and analyse actuarial models with the help of probability theory, statistics and economic theories.
- LO4: Able to design the insurance policies.

UNIT-I: Theory of Interest rates: Rate of interest; Nominal rate of interest. Accumulation factors. Force of interest, present values, Stoodley's formula for the force of interest, present value of cash flows, valuing cash flows. Basic compound interest function, equations of values and yield on transaction-annuities certain, present values and accumulation, concepts of different annuities, continuously payable annuities, varying annuities.

UNIT-II: Utility theory, insurance and utility theory, models for individual claims and their sums, Approximations for the distribution of the sum. Application to insurance. Survival function Time until-death for a person aged x , curate future lifetime, force of mortality.

UNIT-III: Life table and its relation with survival function, examples, the deterministic survivorship group, recursion formulas, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

UNIT-IV: Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, Life annuities: Single payment, continuous life annuities, discrete life annuities, Life

annuities with m^{th} monthly payments, recursions, complete annuities-immediate and apportionable annuities-due.

UNIT-V: Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions, evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrements, central force assumptions for multiple decrements. Uniform distribution assumption for multiple decrements.

Text Books:

N.L. Bowers, H.U. Gerber, J.C. Hickman, D.A.Jones and C.J.Nesbitt, (1986): Actuarial Mathematics, Society of Actuaries, Ithaca, Illinois, U.S.A.Second Edition (1997)

Chapters: 1,2,3,4,5,9 &10

J.J.McCutcheon and W.F.Scott: An Introduction to Mathematics of Finance, Butter Worth & Heinemann

Reference Books:

Spurgeon E.T.(1972): Life Contingencies, Cambridge University Press.

Neill A (1977) Life Contingencies, Heinemann

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Optional Paper (c): KNOWLEDGE DISCOVERY AND DATA MINING

Course Outcomes:

- CO1: Able to outline classification methods.
- CO2: To get expertise in different clustering methods.
- CO3: Able to learn unsupervised learning techniques.
- CO4: To acquaint with supervised learning techniques.
- CO5: Able to get familiarity with analytical data processing.

Course Specific Outcomes:

- CSO1: To demonstrate classification using decision tree.
- CSO2: To contrast clustering method with respect to statistical view point vs data mining view point.
- CSO3: To experiment univariate and multivariate data in unsupervised learning.
- CSO4: To appraise regression trees in predictive modelling.

Learning Outcomes:

- LO1: Able to perform multivariate analysis with data sets.
- LO2: Able to infer vector quantization methods.
- LO3: Obtain a firm foundation in dimension reduction, feature selection and clustering techniques.
- LO4: To construct association rules on data sets.

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

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

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

UNIT-IV: Supervised learning from moderate to high dimensional input spaces; regression trees.

UNIT-V: Introduction to databases, including simple relational databases; data warehouses and introduction to online analytical data processing. Association rules and prediction; data attributes.

Text Books:

- A.Berson and S.J. Smith (1997): Data Warehousing, Data Mining and OLAP. McGraw-Hill.
- L.Breiman, J.H. Friedman, R.A. Olshen, and C.J.Stone (1984): Classification Regression Trees. Taylor Francis.

J.Han and M. Kamber (2006): Data Mining; Concepts and Techniques. 2nd Edition. Morgan Kaufmann.

T.M. Mitchell (2011): Machine Learning. Springer.

Reference Book:

B.D.Ripley (2008): Pattern Recognition and Neural Networks. Cambridge University Press.

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Optional Paper (d): RELIABILITY AND SURVIVAL ANALYSIS

Course Outcomes:

- CO1: Able to understand elements of reliability, hazard function and its applications.
- CO2: Able to estimate the parameters of lifetime distributions.
- CO3: Learn various statistical lifetime models.
- CO4: Can distinguish between the concepts IFR, IFRA, NBU, DMRL, and NBUE.

Course Specific Outcomes:

- CSO1: Know the concepts bounds on system reliability; structural and reliability importance of components.
- CSO2: Learn reliability theory and analysis of survival data.
- CSO3: Familiar with different concepts of reliability and lifetime models.
- CSO4: Able to estimate the reliability of each system component for coherent systems.

Learning Outcomes:

- LO1: Expertize with various statistical lifetime models.
- LO2: Can apply various shock models to the real life data.
- LO3: Expertize with maintenance and replacement policies
- LO4: Get theoretical knowledge of computing probability of survival of machines, models related to production in industries and can draw conclusions.

UNIT-I: Reliability concepts and measures; components and systems; coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on system reliability; structural and reliability importance of components.

UNIT-II: Life distributions; reliability function; hazard rate; common life distributions-exponential, Weibull, gamma etc. Estimation of parameters and tests in these models.

UNIT-III: Notions of ageing; IFR, IFRA, NBU, DMRL, and NBUE Classes and their duals; loss of memory property of the exponential distribution; closures or these classes under formation of coherent systems, convolutions and mixtures.

UNIT-IV: Univariate shock models and life distributions arising out of them; bivariate shock models; common bivariate exponential distributions and their properties.

UNIT-V: Reliability estimation based on failure times in variously censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation. Maintenance and replacement policies; availability of repairable systems.

Text Books:

- Barlow R.E. and Proschan F.(1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless J.F. (2002): Statistical Models and Methods of Life Time Data. 2nd Edition. John Wiley.

Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models. 2nd Edition. CRC Press.
Nelson, W (2003): Applied Life Data Analysis; Wiley Interscience.

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Optional Paper (e): BIOSTATISTICS

Course Outcomes:

- CO1: Able to understand different statistical methods in clinical trials and their applications.
- CO2: Demonstrate different types of statistical designs and perform randomization.
- CO3: Summarize the biological assays such as parallel-line assay, slope-ratio assay and quantile- responses assay.
- CO4: Able to carry out the Categorical Data Analysis, Logistic Regression Analysis and Poisson Regression Analysis and their applications.
- CO5: Able to measure the ANOVA for one way and two way classified data.

Course Specific Outcomes:

- CSO1: Able to conduct trails using simple randomized design, stratified randomized crossover design and sequential design.
- CSO2: Able to apply Wald's statistic and logistic regression in categorical analysis.
- CSO3: Able to understand the properties of ROC curve, Kullback-Leibler Divergence and slope of ROC curve.
- CSO4: Can estimate the measures of diseases frequency and analyse the data using Case control study design.

Learning Outcome:

- LO1: Familiarize with clinical trials and its phases I, II, III and IV.
- LO2: Students learn how to conduct analysis such as categorical analysis, ROC curve analysis and biological assays.
- LO3: Students gain knowledge about various types of regression techniques used to apply medical data especially for count data.
- LO4: Students can perform repeated measures for ANOVA one way and two way classified data.
- LO5: Students can infer about disease frequency, incidence, prevalence and relative risk.

UNIT-I: Statistical Methods in Clinical Trials: Introduction to clinical trial and its phases I, II, III and IV, statistical designs-fixed sample trials: simple randomized design, stratified randomized crossover design; Sequential design - open and close sequential design. Randomization Dynamic randomization, Permuted block randomization; Blinding-Single, double and triple.

UNIT-II: Biological Assays: Introduction, parallel-line assay, slope- ratio assays and quantile-response assay, Feller's theorem. Dose-response relationships-qualitative and quantitative response, dose response relation- estimation of median effective dose – PK-PD Analysis.

UNIT-III: Categorical Data Analysis: Categorical response data, logistic regression-odds ratio, Wald's statistic, logistic regression and its diagnostics, - Poisson regression – Estimation of relative risk and its applications.

UNIT-IV: ROC Curve analysis - Estimation of Binomial Model and the Area under the Curve, its applications – Properties of ROC curve - Kullback –Leibler Divergence (KLD)– definition – functional relationship between Kullback –Leibler Divergence and the slope of the ROC curve – derivations of KLD expressions for Bi-normal ROC model.

UNIT-V: Repeated Measures ANOVA – One Way and Two Classified Data –Measures of disease frequency – incidence – prevalence – relative risk – Epidemiological study designs – Cohort study design and its analysis – Case control study design and its analysis – concept of bias – information bias and selection bias.

Text Books:

1. Elisa T.Lee and John Wenyu Wang (2003): Statistical Methods for Survival Data analysis, 3rd edition, John Wiley.
2. Jerrold H. Zar (1999): Biostatistical Analysis, 4th edition, Pearson.
3. Armitage, P, Berry G and Mathews J.N.S (2002): Statistical Methods in Medical Research, 4th edition, Blackwell Scientific Publications.
4. Krzanowski, W and Hand, D.J. (2009): ROC Curves for Continuous Data, Chapman and Hall.

Reference Books:

1. Hosmer and Lemeshow (2000): Applied Logistic Regression, 2nd , Wiley Series.
2. Alan Agresti (2002): Categorical Data analysis, 2nd , John Wiley.
3. Sylvia Wasserthial and Smoller, (2004): Biostatistics and Epidemiology – A Primer for Health and Biomedical professionals, 3rd edition, Springer.
4. Rastogi, V.B. (2006): Fundamentals of Biostatistics, ANE Books, India.