DEPARTMENT OF STATISTICS, UNIVERSITY OF KERALA
M.Sc. PROGRAMME IN STATISTICS
(Under Credit and Semester System w.e.f.2017 Admission)

Objectives

The main objective of the programme is to equip students with high level of knowledge on statistical theory and practice so as to give a solid background for further intensive studies and research in the area of statistical theory and its applications. Also the course aims to enable students to become efficient Statisticians/Statistical Officers/Research Officers/ Statistical Analytics etc. through occupying positions in research centres/ Govt. Offices/Corporate Offices/ Banks/ Planning Departments/Pharmaceutical Companies etc., where expertize on data analysis or use of statistical techniques are essential components.

Structure of the Programme

Sem. No.	Course code	Name of the Course	Number of Credits
I	Core Courses		
	STA-C-411	Measure Theory	4
	STA-C-412	Mathematical Methods	4
	STA-C-413	Distribution Theory	4
	STA-C-414	Statistical Computing	4
II	Core Courses		
	STA-C-421	Sampling Theory	4
	STA-C-422	Applied Statistics	4
	STA-C-423	Multivariate Analysis	4
	STA-C-424	Probability Theory	4
	STA-C-425	Practical 1	2
III	Core Courses		
	STA- C-431	Stochastic Processes	4
	STA-C-432	Estimation	4
	STA-C-433	Testing of Hypotheses	4
	Internal Electives		
	STA-E-434(i)	Statistical Quality Control and Reliability Modeling	4
	STA-E-434(ii)	Advanced Probability Theory	4
	STA-E-434(iii)	Data Mining	4
IV	Core Courses		
	STA-C-441	Nonparametric Methods	4
	STA-C-442	Design and Analysis of Experiments	4
	STA-C-443	Practical 2	2

	Internal Electives STA-E-444(i) STA-E-444(ii) STA-E-444(iii) STA-E-445(i) STA-E-445(ii) STA-E-445(iii) Dissertation STA-D-446	 Operations Research Bayesian Inference Order Statistics Regression Analysis and Econometric Methods Actuarial Statistics Biostatistics Dissertation	 4 4 4 4 4 4 4
Extra Departmental Elective Courses			
II	STA-X-421	Elements of Probability Theory	2
III	STA-X-431	Elementary Statistical Methods	2

STA – Representing Department of Statistics .C, E and X –Representing Core, Internal elective and Extra Departmental Elective Courses, respectively. First numerical number 4 representing Programming level for PG. Middle numerical number 1,2,3 and 4 representing Semester 1,2,3 and 4 respectively.

Last numerical number 1,2,3 etc. representing Course Numbers.

SEMESTER **:** I
COURSE CODE **:** STA-C-411
COURSE TITLE **:** MEASURE THEORY
CREDITS **:** 4

AIM: The aim of this course is to impart the students the knowledge of measure theory to treat any problem in Mathematical Statistics in a measure theoretic approach so that the results developed in Measure Theory can be adopted as such in the statistical problem of their curriculum.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Measure Theory, which serves as a pre-requisite to any course in Mathematical Statistics such as Probability Theory, Distribution Theory, Stochastic Process Estimation, Testing of Hypothesis, Non-Parametric Methods, Bayesian Inference (Elective), Advanced Probability Theory (Elective) and Order Statistics (Elective).

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

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

SEMESTER **:** I
COURSE CODE **:** STA-C-412
COURSE TITLE **:** MATHEMATICAL METHODS
CREDITS **:** 4

AIM: The course is given as a prerequisite to the papers such as Distribution Theory, Multivariate Analysis, Probability Theory, Estimation, Testing of Hypothesis, Non-Parametric Methods, Stochastic Process, Advanced Probability Theory (Elective), Real Analysis and Econometric Methods (Elective), Bayesian Inference (Elective), Order Statistics (Elective), Actuarial Statistics (Elective) and Operations Research (O.R) (Elective).

OBJECTIVES: Attainment of analytical skills to analyze problems in Statistics is highly essential. The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Mathematical Methods. STA 512: Mathematical Methods is designed in such a manner to impart knowledge on Real Analysis, Theory of Integrals, Vector Spaces and Matrix Theory and Quadratic Forms.

COURSE CONTENT:

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

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

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

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

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

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

REFERENCES

Dissertation

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

SEMESTER **:** I
COURSE CODE **:** STA-C-413
COURSE TITLE **:** DISTRIBUTION THEORY
CREDITS **:** 4

AIM: This is a basic course in Statistics and the aim of this course is to introduce the student the variety of basic distributions in Statistics and dealing with their properties and interrelations. This is also a prerequisite course to the courses such as Estimation, Testing of Hypothesis and Order Statistics (Elective).

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Distribution Theory. The course makes the students to identify an appropriate statistical distribution to a given real life data. Most of the basic univariate continuous and discrete type distributions are discussed together with their properties. Then distribution of functions of random variables which have many applications in practical situations are introduced.

COURSE CONTENT

MODULE I : Basic concepts in distribution theory : p.g.f., m.g.f., and characteristic function. Univariate distributions: Binomial, Negative Binomial, Poisson, Hyper geometric, Geometric, Beta, Gamma, Normal, Log-Normal, Pareto, Weibull, Cauchy. Laplace, Logistic, Log-logistic. Rayleigh and Generalized exponential distributions.

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

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

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

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

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

REFERENCES

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

SEMESTER **:** I
COURSE CODE **:** STA-C-414
COURSE TITLE **:** STATISTICAL COMPUTING
CREDITS **:** 4

AIM: To develop the skill of **s**tudents to write programs using R language and thereby making them capable to do statistical analysis using their own programs.

OBJECTIVES: For applications of statistical methods to various problems arising in real life situation the presently available statistical softwares are used. But there are situations in which software application alone may not solve the problem and sometimes the students have to deal with statistical application in the absence of proper software. Hence this course is designed in such a way that the students attain a caliber of writing computer programs to statistical problem by their own way.

COURSE CONTENT

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

MODULE II: An overview of the R Language- Expressions, Objects, Symbols, Functions, Special Values. R Syntax- Constants, Numeric vectors, Character vectors, Symbols, Operators, Order of operations, Assignments, Expressions, Control Structures- Conditional Statements, Loops, Accessing data Structures, R Objects- Vectors, Lists, Matrices, Arrays, Factors, Data Frames, Formulas, Time series.

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

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

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

One way ANOVA and its nonparametric version. Goodness of fit tests, Simple correlation and regression.

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

REFERENCES

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

SEMESTER **:** II
COURSE CODE **:** STA-C-421
COURSE TITLE **:** SAMPLING THEORY
CREDITS **:** 4

AIM: Planning and execution of a survey is a common practice in every field of life to collect information about various characteristics of the population. The aim of this course is to make the student competent to organize, supervise and execute any survey related statistical work and to carry out research in sampling theory.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Sampling. Theory This is a well designed course covering all important sampling methods. Various estimation techniques have also been considered.

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

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

SEMESTER **:** II
COURSE CODE **:** STA-C-422
COURSE TITLE **:** APPLIED STATISTICS
CREDITS **:** 4

AIM: This course is meant with the aim of imparting knowledge for making the students competent enough to execute any applied statistical problem.

OBJECTIVES: This course gives an exposure of importance in applied statistics problems such as Time Series, Index Numbers, Vital Statistics/Demography and Official Statistics with special reference to Indian Statistical System.

COURSE CONTENT

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

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

MODULE III: Detailed study of the linear time series models: Autoregressive processes - Stationarity conditions, Autocorrelation function, Yule Walker estimation for AR processes and

Partial autocorrelation function, Moving average process - Invertibility conditions, Autocorrelation function and Partial autocorrelation function.

MODULE IV: Economic Statistics: The problem of Index Numbers, Calculation of the Indexes – Ratio of simple aggregates, Ratio of weighted aggregates, Choice of a base period, fixed base and chain base methods- Advantages and disadvantages, Errors in Index Number Formulae-Formula error, Sampling error and Homogeneity error. Different Tests of a good Index Number-Unit test, Time Reversal test, Factor reversal test and circular test. Cost of living Index Number.

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

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

REFERENCES

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

SEMESTER : II
COURSE CODE : STA-C-423
COURSE TITLE : MULTIVARIATE ANALYSIS
CREDITS : 4

AIM: Multivariate Analysis is an important core area in Statistics. Imparting knowledge through this course makes the students competent in pursuing for research in this area as well as for carrying out multivariate data analysis. This course is also a prerequisite to the elective course "STA 501- Data Mining".

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Multivariate Analysis. It deals with methodologies necessary to analyze data arising from populations with multivariate measurements made on the units.

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

- Anderson, T.W. (2003) :An Introduction to Multivariate Statistical Analysis, John Wiley, New York.
- Graybill, F. A. (1961): An Introduction to Linear Statistical Model, Vol. 1, McGraw Hill, New York.
- Johnson, R and Wychern (1992): Applied Multivariate Statistical Analysis, Prentice hall, London.
- 4. Kendall, M. G. (1958) :A Course in Multivariate Analysis, Griffin, London.
- Khatri, C.G. and Srivastava (1979) : An Introduction to Multivariate Statistics, North – Holland, New York.
- Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley & Sons New York.
- Rao, C.R.(1973) : Linear Statistical Inference and its Applications, Wiley Eastern, New York.
- Rohatgi, V.K.(1976): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd, New York.

SEMESTER **:** II
COURSE CODE **:** STA-C-424
COURSE TITLE **:** PROBABILITY THEORY
CREDITS **:** 4

AIM: Theory of probability plays a crucial role in the advanced fields of science. Hence it is necessary for a Statistic student to undergo this course. This paper is also a prerequisite to take up the elective course "Elective 1-B: Advanced Probability Theory".

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Probability Theory. The course is meant to introduce the theory related to probability for students of Statistics. This is also an important core paper in Statistics dealing with all probability theories necessary for acquiring enough knowledge for applications of those theories in other statistical papers in the M.Sc. (Statistics) curriculum.

COURSE CONTENT

MODULE I: Probability space, limit of sequence of events, monotone and continuity properties of probability measure, addition theorem, independence of finite number of events, sequence of

events, tail events and tail fields, Borel Cantelli lemma, Borel zero one law. Conditional Probability and Bayes Theorem.

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

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

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

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

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

REFERENCES

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

SEMESTER **:** II
COURSE CODE **:** STA-C-425
COURSE TITLE **:** PRACTICAL-I
CREDITS **:** 2

AIM: The aim of this course is to make a student competent in writing programs using R and do data analysis.

OBJECTIVES: Pursuing this course will help the students to write programs using R to tackle any data analysis problem. Further the students do data analysis exercise using the software SPSS for problems that arise in the courses that they have taken up in the first two semesters.

COURSE CONTENT

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

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

MODULE III: (Using R programming) Selection of a random sample :Simple random sample with and without replacement, PPS sample, with and without replacement, Midzuno-Sen sample ,linear systematic sample, circular systematic sample, multiple start systematic sample. Estimation; Estimate of population mean (total) and estimate of standard error of the estimate of mean(total based upon a simple random sample with or without replacement, linear systematic sample, circular systematic sample, multiple start systematic sample ,stratified random sample, cluster sample, two stage sample. Estimated gain in efficiency due to stratification,

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

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

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

SEMESTER : III
COURSE CODE : STA- C-431
COURSE TITLE : STOCHASTIC PROCESSES
CREDITS : 4

AIM: This is a prerequisite course to undergo the elective courses "Elective 2-A:STA 502- Operations Research" and "Elective 3-B:STA 503- Actuarial Statistics".

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Stochastic Processes.

COURSE CONTENT

MODULE I: Basic concepts. Family of random variables and their distributions, Kolmogorov consistency theorem(without proof), Introduction to Stochastic processes, time and state space, classification of stochastic processes, processes with stationary independent increments, Markov process, renewal process, martingales, Wiener process, Gaussian process (definitions and examples).

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

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

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

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

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

REFERENCES

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

- Parzen, E. (1962): Stochastic Processes, Holden-Day Inc, San Francisco.
- Srinivasan, S.K. and Mehata, K.M. (1976): Stochastic Processes, Tata McGraw-Hill Publishing Company Limited, New Delhi.

SEMESTER **:** III
COURSE CODE **:** STA-C-432
COURSE TITLE **:** ESTIMATION
CREDITS **:** 4

AIM: This course is meant to impart knowledge on parametric estimation and Bayesian methods of estimation to the students.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Estimation. The course will also empower the student to fix up an estimation method and attempt on it to estimate the parameters of any distribution that he/she come across in dealing with problems of Statistics. An introduction to Bayesian approach in dealing with estimation problems is also dealt with.

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

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

SEMESTER **:** III
COURSE CODE **:** STA-C-433
COURSE TITLE **:** TESTING OF HYPOTHESES
CREDITS **:** 4

AIM: In various fields of research, hypotheses have been formulated and subjected to studies based on available data. To establish this theories a statistical approach is necessary. It is done through testing of hypothesis. The aim of this paper is to make familiarize with all problems that arise in testing of hypothesis.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Testing of Hypotheses. Here, the important principles and methodologies of testing of hypothesis problems are included. Connection of Interval Estimation with Testing of Hypothesis and applications sheered undergoing this coursemake the students competent to apply these principles to tackle all testing problems they come across in any situation.

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

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

SEMESTER **:** III
COURSE CODE **:** STA-E-434(i)
COURSE TITLE **:** STATISTICAL QUALITY CONTROL AND RELIABILITY MODELING
CREDITS **:** 4

AIM: This course is aimed to make the students competent to familiarize the Industrial applications of Statistics and modeling and analysis of life length data.

OBJECTIVES: Modeling and analysis of life length data is an important aspect of statistical work in a wide variety of scientific and technological field. Quality control is a prime area in industry. Hence this course is designed in such a manner that students gain knowledge in statistical analysis of life time data which has many applications in the field of Engineering, Medicine and Biological Sciences and make familiarize the industrial applications of Statistics especially in Quality control.

COURSE CONTENT

MODULE I: Statistical process control, Theory of control charts – Shewart control charts for variables- $\bar{X}$, R,S charts, Attribute control charts - np, p, c and u charts – OC, ARL & process capability of control charts, CUSUM charts, Acceptance sampling for attributes and variables.

MODULE II: Sampling inspection techniques: Single, double and multistage sampling plans and their properties, Chain sampling, Continuous sampling, Taguchi method, Total quality management, ISO standardization, ISO 9001, six sigma concepts.

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

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

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

REFERENCES

- Barlow, R.E. and Proschan, F. (1985): Statistical Theory of Reliability and Life Testing, Holt, Rinehart and Winston.
- Cox, D.R. and Oakes, D. (1984): Analysis of Survival Data, Chappman Hall.
- Duncan, A. J. (1959): Quality Control and Industrial Statistics (5th edition), Irwin, Homewood I.
- Galambos, J. and Kotz, S. (1978) Characterization of Probability Distributions.
- Klefjo, B. (1982) The HNBUE and HNWUE Classes of Life distributions, Naval Research Logistic Quarterly, 29, 331-344.

- Lawless, J. F. (2003): Statistical Models and Methods for Lifetime Data, John Wiley.
- Montgomery, D.C. (2005): Introduction to Statistical Quality Control, 5th edition, John Wiley.
- Nelson, W. (1982): Applied life data analysis, Wiley.
- 9. Sinha, S. K. (1986) Reliability and Life Testing, Wiley.

SEMESTER **:** III
COURSE CODE **:** STA-E-434(ii)
COURSE TITLE **:** ADVANCED PROBABILITY THEORY
CREDITS **:** 4

AIM: This course is meant for students who are interested to do research in Probability Theory.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of new concepts in Probability Theory. Advance methods of probability have been considered with the purpose of motivating research in this area.

COURSE CONTENT

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

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

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

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

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

REFERENCES

- Laha, R. G. and Rohatgi, V. K. (1979): Probability Theory, John Wiley & Sons, New York.

- Feller, W. (1968) : An Introduction to Probability Theory and Its Applications, Vol 1, John Wiley, New York.
- Feller, W. (1971): An Introduction to Probability Theory and Its Applications, Vol. 2, John Wiley, New York.
- Fisz, M. (1963): Probability Theory and Mathematical Statistics, John Wiley, New York.

SEMESTER **:** III
COURSE CODE **:** STA-E-434(iii)
COURSE TITLE **:** DATA MINING
CREDITS **:** 4

AIM: To train students how to analyze data and make conclusion from it.

OBJECTIVES: This course deals with applications of statistical techniques for data classification, dimension reduction, online analytical data processing, artificial neural networks and applications to e-commerce.

COURSE CONTENT

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

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

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

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

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

REFERENCES

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

Regression Trees. Wadsworth and Brooks/Cole.
- Han, J. and Kamber, M. (2000): Data Mining; Concepts and Techniques. Morgan Gaufmann.
- Mitchell, T.M. (1997): Machine Learning. McGraw-Hill.
- Ripley, B.D. (1996): Pattern Recognition and Neural Networks. Cambridge University Press.

SEMESTER **:** IV
COURSE CODE **:** STA-C-441
COURSE TITLE **:** NONPARAMETRIC METHODS
CREDITS **:** 4

AIM: This is a course meant to equip the students to tackle statistical problems both estimation and testing which arise in cases where the basic population distribution is unspecified.

OBJECTIVES: Various nonparametric techniques in Estimation and Testing of Hypothesis are described.

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

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

SEMESTER **:** IV
COURSE CODE **:** STA-C-442
COURSE TITLE **:** DESIGN AND ANALYSIS OF EXPERIMENTS
CREDITS **:** 4

AIM: This is a course which is important both in the sense of studying a theory and in terms of its extensive applications in the areas of Agriculture, Medicine, Clinical Trials, Industry and so on. Undergoing this course make the students to pursue research in this area as well as to apply this theory to any real life problems they come across.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Design of Experiments. Here, all basic experimental designs and analysis based on these designs are introduced.

COURSE CONTENT

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

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

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

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

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

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

REFERENCES

- Aloke Day (1986). Theoryof Block Designs .Wiley Eastern, New Delhi.
- Chakrabarti,M.C.(1962) : Mathematics of Design and Analysis of Experiments , Asia Publishing House, Bombay.
- Das, M. N. and Giri, N. (1979). Design and Analysis of Experiments. Wiley Eastern Limited, New Delhi.
- John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan.
- Joshi, D. D. (1987): Linear Estimation and Design of Experiments, Wiley Eastern, Wiley Eastern Limited, New Delhi.
- Montgomery,C.D.(1976): Design and Analysis of Experiments, John Wiley, New York.

SEMESTER **:** IV
COURSE CODE **:** STA-C-443
COURSE TITLE **:** PRATICAL 2
CREDITS **:** 2

AIM: The main aim of this course is to equip the students with working knowledge of problems that arise with Estimation and Testing of parameters of populations having specified as well as non specified distributions and various designs of practical experiments.

OBJECTIVES: Problems in Statistical Inference and Design of Experiments have been worked out.

COURSE CONTENT

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

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

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

MODULE IV: (Using R) Nonparametric tests – Sign test, Wilcoxon signed rank test, run test., Median test. Kendall's rank order correlation coefficient and Kendall's coefficient of concordance as measure of association. Test based on Mann-Whitney Statistics. Friedman two way analysis of variance by ranks.

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

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

SEMESTER **:** IV
COURSE CODE **:** STA-E-444(i)
COURSE TITLE **:** OPERATIONS RESEARCH
CREDITS **:** 4

AIM: To equip the students with knowledge in Statistics to become efficient managers.

OBJECTIVES: This course is meant to give an introduction to various types of optimization problems including linear and nonlinear programming problems,that mainly arise in management science. Students with deep knowledge in Statistics can excel in the field of management with their knowledge in Operations Research course offered in this semester.

COURSE CONTENT

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

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

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

MODULE IV: Queuing theory: Basic structure, Role of the Poisson and exponential distributions.
M|M|1, M|M|C, M|Ek|1 and M|G|1 queues and their properties. Waiting time distributions, Steady
state solution.

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

REFERENCES

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

SEMESTER **:** IV
COURSE CODE **:** STA-E-444(ii)
COURSE TITLE **:** BAYESIAN INFERENCE
CREDITS **:** 4

AIM: Bayesian inference allows priors so that prior knowledge or results of a previous model can be used to inform the current model. This can avoid problems with model identification by manipulating prior distributions (usually in complex models). So a student with Statistics background can do Bayesian analysis in an efficient manner by undergoing this course.

OBJECTIVES: This course is meant to give an introduction to point estimation, interval estimation, hypothesis testing and prediction problems using Bayesian approach.

COURSE CONTENT

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

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

MODULE III: Bayesian point estimation: as a prediction problem from posterior distribution. Bayes estimators for (i) absolute error loss (ii) squared error loss (iii) 0 - 1 loss. Generalization to convex loss functions. Evaluation of the estimate in terms of the posterior risk.

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

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

REFERENCES

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

SEMESTER **:** IV
COURSE CODE **:** STA-E-444(iii)
COURSE TITLE **:** ORDER STATISTICS
CREDITS **:** 4

AIM: Order Statistics play a crucial role in Statistical Theory and Methodology. Several simple functions of Order Statistics are extensively used in many practical investigations in the fields of Hydrology, Aeronautics, Oceanography, Meteorology and Engineering. Hence this course aims to equip a student to make contributions in these practical fields as well as for further research in this area.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Order Statistics.

COURSE CONTENT

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

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

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

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

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

REFERENCES

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

SEMESTER **:** IV
COURSE CODE **:** STA-E-445(i)
COURSE TITLE **:** REGRESSION ANALYSIS AND ECONOMETRIC METHODS
CREDITS **:** 4

AIM: To equip the student with sound skill in analyzing economic data, developing econometric models and its interpretation.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Regression and Econometrics. This course also introduces various aspects of multiple regression models, polynomial regression models and important econometric models.

COURSE CONTENT

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

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

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

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

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

REFERENCES

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

SEMESTER **:** IV
COURSE CODE **:** STA-E-445(ii)
COURSE TITLE **:** ACTUARIAL STATISTICS
CREDITS **:** 4

AIM: The aim of this course is to equip a student to make contributions in the field of Actuarial Statistics as well as those who are interested to bring up efficient Actuaries.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Actuarial Statistics. Actuarial Statistics is based on the evaluation of the financial, economic and business implications of future contingent events based on Statistical concepts. It is very useful in the business world, usually within the Insurance Industry. This course is meant for molding a student to get ample opportunities in the field of Insurance and Banking.

COURSE CONTENT

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

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

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

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

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

REFERENCES

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

SEMESTER **:** IV
COURSE CODE **:** STA-E-445(iii)
COURSE TITLE **:** BIOSTATISTICS
CREDITS **:** 4

AIM: To introduce some important concepts of Statistics related to Clinical Trials/Medical Research.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of basic concepts in Biostatistics. Application of Statistical techniques in various biological fields are dealt with.

COURSE CONTENT

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

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

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

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

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

REFERENCES

- Biswas, S. (1995): Applied Stochastic Processes. A Biostatistical and Population Oriented Approach, Wiley Eastern Ltd.
- Cox, D.R and Oakes, D. (1984): Analysis of Survival Data, Chapman and Hall.
- Elandt, RC. and Johnson (1975): Probability Models and Statistical Methods in Genetics, John Wiley & Sons.
- Ewens, W. J. (1979): Mathematics of Population Genetics, Springer Verlag.
- Ewens, W. J. and Grant, G.R (2001): Statistical methods in Bioinformatics: An

Introduction, Springer.
- Friedman, L.M., Furburg, C. and DeMets, D.L. (1998): Fundamentals of Clinical Trials, Springer Verlag.
- Gross, A. J. and Clark, V.A. (1975): Survival Distribution; Reliability Applications in Biomedical Sciences, John Wiley & Sons.

SEMESTER **:** IV
COURSE CODE **:** STA-D-446
COURSE TITLE **:** DISSERTATION
CREDITS **:** 4

AIM: The course is meant to kindle interest in the students to think in an innovative manner so as to create the problems in statistical study involving some planning, sampling and applications of the methods they have studied at the post graduate curriculum.

OBJECTIVES: As per this course a student has to submit either a Dissertation or Project Report. The dissertation work means a review of recently developed theories in Statistics whereas in the Project work the student has to choose a real life problem and its statistical study based on primary/secondary data. The submission of the project report/dissertation is compulsory for the successful completion of the course.

SEMESTER **:** II
COURSE CODE **:** STA-X-421
COURSE TITLE **:** ELEMENTS OF PROBABILITY THEORY
CREDITS **:** 2

AIM: The aim of this course is to impart the students the basic knowledge of Probability Theory.

OBJECTIVES: The course will consist of lectures and related activities that will help in developing good understanding of elementary concepts of Probability Theory. Thus the course will enable the student to do further studies/research in this area as well as areas like Stochastic Processes, Queueing Theory etc.

COURSE CONTENT

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

MODULE II: Random variable, its probability distribution and distribution function, properties of distribution function, expectation and moments of random variables, Markov and Liaponov inequalities.
MODULE III: Characteristic function and their elementary properties, uniform continuity and non-negative definiteness of characteristic function, inversion theorem (proof not required), uniqueness theorem, Fourier inversion theorem, continuity theorem (proof not required), Bochner-Khintchine theorem of characteristic functions(proof not required).

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

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

REFERENCES

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

SEMESTER **:** III
COURSE CODE **:** STA-X-431
COURSE TITLE **:** ELEMENTARY STATISTICAL METHODS
CREDITS **:** 2

AIM: To introduce elementary statistical techniques so that the student will become familiar with some basic concepts useful for conducting a surveys/experiment, analyzing data and drawing valid conclusions.

OBJECTIVES: The course will consist of lectures and related activities that will help in creating awareness about basic concepts in using statistical techniques, which are useful in research activities in their areas.

COURSE CONTENT

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

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

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

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

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

REFERENCES

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