COURSE STRUCTURE & REGULATIONS

FOR THE TWO YEAR M.Sc.

IN

STATISTICS

(Approved by the Post-Graduate Board of Studies)

West Bengal State University

(Barasat, NORTH 24 PARGANAS)

ACADEMIC SESSION: 2009-2011

Regulations for the M.Sc in Statistics Examination

- **Conventionally a semester consists of 14 weeks and for a course carrying 1 Credit Point (CP), 14 lectures, each with one hour duration, is required.**
- **The 1000 Marks, 80 CP course has been divided into 18 theoretical (675 Marks, 54 CP) and 5 experimental (325 Marks, 26 CP) courses. Experimental sections include Practical, Assignments and Seminar.**
- **The particulars of the examination (e.g. duration, assessment procedure), minimum qualifying marks for a course and for a semester will be in accordance with the existing university regulations.**

Part 1, 1st Semester

Courses Offered:

Theoretical		**175 Marks, 14 CP**
STA 501	**Mathematical Analysis**	**50 Marks, 4 CP**
STA502	**Distribution Theory I & Statistical Inference I**	**50(25+25) Marks, 4 CP**
STA503	**Linear Algebra, Linear Models & Mathematical Programming**	**50(35+15) Marks, 4 CP**
STA504	**Survey Methodologies**	**25 Marks, 2 CP**

Practical		**75 Marks, 6 CP**
STA505(I)	**Statistical Computing I**	**35 Marks**
STA505(II)	**Statistical Computing II**	**35 Marks**
STA505(III)	**Viva-Voce**	**05 Marks**

Examination for STA 505(I) will be computer based on the topics covered in C and R and STA 505(II) comprises of applications computer & calculator based practical on the theoretical topics taught in STA 502-504.

Part 1, 2nd Semester

Courses Offered:

Theoretical		**175 Marks, 14 CP**
STA 511	**Probability Theory**	**50 Marks, 4 CP**
STA 512	**Design of Experiments & Statistics for Development**	**50(35+15) Marks, 4 CP**
STA 513	**Statistical Inference II & Regression Analysis**	**50(25+25) Marks, 4 CP**
STA 514	**Distribution Theory II**	**25 Marks, 2 CP**

Practical **75 Marks, 6 CP**

STA 515(I)	**Statistical Computing I**	**35 Marks**
STA 515(II)	**Statistical Computing II**	**35 Marks**
STA 515(III)	**Viva-Voce**	**05 Marks**

Examination for STA 515(I) will be based on statistical analysis using statistical packages and STA 515(II) comprises of computer & calculator based applications on the theoretical topics taught in STA 512-514.

Part 2, 1st Semester

Courses Offered:

Theoretical **175 Marks, 14 CP**

STA521	**Advanced Paper 1-Section I**	**25 Marks, 2 CP**
STA522	**Advanced Paper 2-Section I**	**25 Marks, 2 CP**
STA523	**Advanced Paper 3-Section I**	**25 Marks, 2 CP**
STA524	**Statistical Inference III**	**50 Marks, 4 CP**
STA525	**Stochastic Process**	**50 Marks, 4 CP**

Practical **75 Marks, 6 CP**

STA 526(I)	**Statistical Computing I**	**35 Marks**
STA 526(II)	**Statistical Computing II**	**35 Marks**
STA 526(III)	**Viva Voce**	**05 Marks**

Examination for STA 526(I) will be based on statistical analysis using statistical packages and that for STA 526(II) will be on the computer & calculator based applications of the theoretical topics taught in STA 521-525. Questions of STA 526(II) will be divided into two groups (Groups A and B). Group A (carrying 20 marks) questions will be based on the advanced theoretical topics (i.e. STA 521-523) and those for Group B (carrying 15 marks) will be based on the general theoretical topics (i.e. STA 524-525).

Part 2, 2nd Semester

Courses Offered:

Theoretical		**150 Marks, 12 CP**
STA 531	**Advanced Paper 1-Section II**	**25 Marks, 2 CP**
STA 532	**Advanced Paper 2-Section II**	**25 Marks, 2 CP**
STA 533	**Advanced Paper 3-Section II**	**25 Marks, 2 CP**
STA 534	**Data Analysis**	**50 Marks, 4 CP**
STA 535	**Applied Multivariate Analysis**	**25 Marks, 2 CP**

Practical		**100 Marks, 8 CP**
STA 536(I)	**Statistical Computing**	**40 Marks**
STA 536(II)	**Project Work**	**50 Marks, 4 CP**
STA 536(III)	**Viva Voce**	**10 Marks**

STA 536(I) will be based on the computer & calculator based applications on the theoretical topics taught in STA 531-535. Questions of STA 536(II) will be divided into two groups (Groups A and B), carrying 20 marks each. Group A questions will be based on the advanced theoretical topics (i.e. STA 531-533) and those for Group B will be based on the general theoretical topics (i.e. STA 534-535). Assessment for STA 536(II) will be based on a seminar presentation with 20 marks for both the project report and presentation of the work and remaining 10 marks for the related viva-voce.

▶*Selecting the Advanced Papers:* **For the selection of advanced papers, students need to select any one of the following modules and any three courses thereof. However, the modules, as well as the optional papers within each module, to be offered in a particular year, will be decided by the Department.**

Module1 : Advanced Applied Statistics

Courses Offered:

1. **Life Data Analysis:**

   Section I: Survival Analysis
   Section II: Clinical Trials
   OR
   Section II: Statistical Genomics & Bioassay
   OR
   Section II: Statistical Epidemiology

2. **Advanced Survey Sampling:**

   Section I: Advanced Survey Methodologies
   Section II: Model-Based Inference in Survey Sampling

3. **Industrial Statistics:**

   Section I: Operations Research
   Section-II: Optimization
   OR
   Section-II: Reliability Theory
   OR
   Section-II: Quality Control Techniques

4. **Advanced Design of Experiments**

Module 2: Advanced Statistical Inference

Courses Offered:

1. **Advanced Statistical Inference**
2. **Bayesian Inference & Semi parametric Methods**
3. **Advanced Non-parametric Inference**
4. **Statistical Decision Theory**

Module 3: Economic & Financial Statistics

Courses Offered:

1. **Advanced Econometric Methods.**
2. **Advanced Time Series Analysis.**
3. **Applied Stochastic Models and Finance**
4. **Advanced Regression Analysis**

DETAILED SYLLABUS: 2009-2011

Part 1, 1st Semester

Mathematical Analysis

Real analysis: Real number system, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass property and Heine-Borel property-statement & applications . [6]

Sequence, series, convergence, real valued function, limit, continuity, uniform continuity, differentiability of univariate and multivariate functions, Mean value Theorems. [9]

Reimann integral, Reimann-Stieltjes integral,Review of sequence and series of functions, Uniform convergence: Term by term differentiation and integration, power series. [8]

Classes of sets, fields, sigma fields, minimal sigma field, Borel sigma field, Sequence of sets, limsup and liminf of a sequence of sets. Measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue-Stieltjes measure. Product measure and Fubini's theorem (statement and use). [12]

Complex analysis: Complex number system, Limit, Continuity and Differentiability, Homomorphic/Analytic functions: Cauchy-Riemann equations, Power series, Complex integration. [15]

References:

T.M.Apostol :Mathematical Analysis
W.Rudin :Principles of Mathematical Analysis
R.R.Goldberg :Methods of Real Analysis
J.C.Burkill :First Course of Mathematical Analysis
J.C.Burkill & H.Burkill :Second Course of Mathematical Analysis
A. Ahlfors : Complex Analysis
S. Shantinarayan : An Introduction to the theory of Analytic functions of complex variables

Distribution Theory I

Distribution theory for many to one transformations [2]
Non central distributions: χ^2 , t and F. [5]
General discussion on Multivariate distributions- Multinomial distribution [5]
Elliptical and Spherical family of distributions- Multivariate Normal Distribution (as a special case) [7]
Distribution of Quadratic Forms-Cochran's Theorem [6]

References :

C.R.Rao :Linear Statistical Inference and its Applications
T.W.Anderson :Introduction to Multivariate Analysis
A.M.Khirsagar :Multivariate Analysis
S.S.Wilks :Mathematical Statistics
M.S.Srivastava & C.G.Khatri :Introduction to Multivariate Statistics
R.J.Muirhead :Aspects of Multivariate Statistical Theory

Statistical Inference I

Data Reduction: Sufficiency and Minimal sufficiency, Completeness, Bounded completeness and Ancillary Statistic, Exponential family of distributions. [8]

Point Estimation: Bhattacharya system of lower bounds, Minimum Variance Unbiased Estimators- Rao-Blackwell & Lehmann-Scheffe Theorems. [7]

Testing Of Hypothesis I: Nonrandomized and Randomized tests, critical function, power function. Most Powerful(MP) Tests-Neyman-Pearson Lemma (Existence, Sufficiency and Necessity). UMP tests: Simple problems for Exponential and Pitman families of distributions. Enlargement technique for testing a composite null against a composite alternative [10]

References :

E.L.Lehmann : Testing Statistical Hypotheses
S.Zacks : The Theory of Statistical Inference
C.R.Rao : Linear Statistical Inference and its Applications
E.L.Lehmann : Theory of Point Estimation
T.S.Ferguson : Mathematical Statistics
Nitis Mukhopadhyay Probability and Statistical Inference
B.K.Ghosh : Sequential Tests of Statistical Hypotheses
D.A.S.Fraser : Nonparametric methods in Statistics
J.O.Berger : Statistical Decision Theory and Bayesian Analysis

Linear Algebra & Linear Models

Linear Algebra: Review of Vector space and Matrix Algebra, Kroneker product of Martices
Singular values and singular value decomposition, Jordan decomposition.
Idempotent matrices and their properties.
Simultaneous diagonalisation of a pair of real symmetric matrices, Extrema of quadratic forms, Choleski Decomposition, Spectral Decomposition.
Generalised Inverse of matrices: Definition and properties, Different techniques of obtaining generalised inverse, Reflexive generalised inverse-Moore Penrose generalised inverse, Obtaining a Moore Penrose generalised inverse using Singular Value Decomposition. [10]

Linear Models: Gauss-Markov model: Estimable functions, BLUE & Gauss Markov Theorem, Estimation space and Error space, Sum of squares due to a set of linear functions, Estimation with correlated observations , Least Square estimation with linear restriction on the parameters. [10]

General linear hypothesis: F test for general linear hypothesis and associated confidence sets, Multiple comparison procedures of Scheffe and Tukey, Applications of general linear hypothesis to regression, analysis of variance and covariance. [10]

Random and Mixed effects models (balanced case): Estimation of variance components. [5]

References :

H.Scheffe :The Analysis of Variance
S.R.Searle :Linear Models
G.A.F.Seber :Linear Regression Analysis
N.Giri :Analysis of Variance
D.D.Joshi :Linear Estimation & Design of Experiments

Mathematical Programming

Convex sets and Convex functions [2]

Linear Programming: Simplex algorithm and Duality Principle [8]

Non – linear programming: Lagrange multiplier technique for equality constraints &. applications of Karush-Kuhn–Tucker (KKT) conditions for inequality constraints.[5]

References :

S.S. Rao :Engineering Optimization
M. S. Bazaraa, Hanif D. Sherali and C. M. Shetty Nonlinear programming: theory and algorithms
Mordecai Avriel Nonlinear Programming: Analysis and Methods

Survey Methodologies

Probability sampling from a finite population [3]

Basic sampling schemes – Simple random sampling with and without replacement, Unequal probability sampling with and without replacement, Systematic sampling. Related estimators of population total/mean, their variances and variance estimators – Mean per distinct unit in simple random with replacement sampling, Hansen Horvitz estimator in unequal probability sampling with replacement, Des Raj and Murthy's estimator (for sample of size two) in unequal probability sampling without replacement. [8]

Stratified sampling – Allocation problem and construction of strata. [3]

Ratio, Product, Difference and Regression estimators. Unbiased Ratio type estimators. Hartley – Ross estimator in simple random sampling. [4]

Sampling and sub-sampling of clusters. Two-stage sampling with equal/unequal number of second stage units and simple random sampling without replacement / unequal probability sampling with replacement at first stage. [4]
Double sampling for stratification. Double sampling ratio and regression estimators. [3]

References :

W.G.Cochran :Sampling Techniques
Des Raj & Chandak :Sampling Theory
A.S.Hedayat & B.K.Sinha :Design & inference in finite population sampling
P.Mukhopadhyay :Theory & Methods of Survey Sampling
M.N.Murthy :Sampling Theory and Methods.

Statistical Computing I(Computing with C & R)

Computing with C: A brief overview of C: Syntax, loops, pointers, arrays, structures, functions, files.

Stochastic simulation: Generation of Random Numbers and selection of samples, Monte Carlo Simulation.

Computing with R:
Basic operations: Basic arithmetic operations (addition, subtraction, multiplication, division etc): Use of R as a scientific calculator.
Graphical display: Stem-leaf plot, Histogram and Density plot, Box plot, Scatter plot.
Descriptive statistics : Simple Descriptive Measures (mean, variance, sum of squares, maximum, minimum, quantiles, correlation coefficient).
Sample drawing techniques: Drawing of random numbers, SRS procedure-with and without replacements..
Matrix Calculations: Vectors and matrices: Basic operations on vector and matrices (addition, multiplication, calculation of quadratic forms).
Determinant, Trace, Rank, Inverse and Solution of linear equations.
Eigenvalues and Eigenvectors of a square symmetric matrix. Spectral Decomposition, Choleski Decomposition
Singular Value Decomposition of any matrix and rank determination. Moore-Penrose Generalized inverse using Singular Value Decomposition**.**

References :

Kernighan and Ritchie : The **C** Programming Language
Hrishikesh Kanitkar Let us C
W. N. Venables and B. D. Ripley : Modern Applied Statistics with S
Michael J. Crawley Statistics: An introduction using R

Part 1, 2nd Semester

Probability Theory

Borel fields & Sigma fields in probability, Probability as a measure, Measurable functions: Random variable as a measurable function.
Integration of a measurable function with respect to a measure.
Sequence of measurable functions: Monotone convergence theorem, Fatou's lemma and Dominated convergence theorem and their probabilistic aspects, Radon-Nikodym theorem (statement and use). [15]
Distribution functions: Application of Lebesgue-Stieltje's measure, Expectation, Generating functions and Characteristic function, Inversion theorem and Continuity Theorem (only statement). Independence-Borel Cantelli Lemma. [15]
Sequence of random variables, Different modes of convergence of a sequence of random variables-- Inter-relations, Weak and Strong laws of large numbers-Kolmogorov's inequality [12]
Central limit Theorem for iid random variables, CLT for a sequence of random variables (statement only) [8]

References :

A.K.Basu : Measure theory and Probability
B.R.Bhat : Modern Probability Theory
P.Billingsley : Probability and Measure
J.F.C. Kingman & S.J.Taylor : Introduction to Measure and Probability
R.G.Laha & V.K.Rohatgi : Probability theory
R. Ash : Real Analysis and Probability

Design of Experiments

Basic principles of design, Elimination of heterogeneity in one and two directions . [2]
General Block designs and its information matrix(C), Concepts of Connectedness, Orthogonallity and Balance,
Intrablock analysis of orthogonal (CRD, RBD, LSD) and non-orthogonal (Balanced Incomplete Block (BIB) and Youden Square(YS)) designs.
Recovery of interblock information in BIB design [16]
Construction of complete classes of Mutually Orthogonal Latin Squares (MOLS);
Construction of BIBD using MOLS and Boses's fundamental method of difference. [9]
Factorial experiment: Confounding and balancing in symmetric factorial experiments-Analysis. [8]

References :

M.C.Chakraborty : Mathematics of Design and Analysis of Experiments

A.Dey : Theory of Block Designs
D.Raghavarao : Constructions & Combinatorial Problems in Design of Experiments
R.C.Bose : Mathematical Theory of Symmetric Factorial (Sankhya - Vol. 8)
R.C.Bose : On the Construction of Balanced Incomplete Block (Annals Eugenics - Vol. 9)
D.C.Montogomery : Design and Analysis of Experiments

Statistics for Development

Economic development: growth in per capita income and distributive justice, indices for development, human development index and physical quality of life index. [3]

Distribution of Income, Pareto and Engel curve, Measures of inequality, Concentration curve, Gini coefficient, Theil's measure. [4]

Poverty measurement, different issues, measures of incidence and intensity, combined measures (Kakwani, Sen indices) [3]

Projection of Population: Projection of labourforce and manpower, Measurement of unemployment. [3]

Other indicators of Development: Agriculture, Industrial growth etc. [2]

References :

CSO (1980) : National Accounts Statistics
N. Keyfitz : Applied Mathematical Demography
UNESCO : Principles of Vital Statistics System - Series M-12
A.Sen : Poverty and Inequality
Y.P. Chaubey : Poverty Measurements: issues, approaches and indices
UNO : Yearly Human Development Reports
World Bank : Yearly Reports

Statistical Inference II

Testing of Hypothesis II: UMP tests for Monotone Likelihood Ratio (MLR) families. Generalised Neyman-Pearson Lemma-UMPU tests for one parameter families, Locally best tests. Similar tests, Neyman structure, UMPU tests for composite hypotheses- nuisance parameters, Behrens-Fisher Problem. [10]

Confidence Interval Estimation: Relation with hypothesis testing, Optimum parametric confidence intervals. [4]

Sequential Analysis: Sequential Probability Ratio test, Termination of SPRT, Wald's equation of ASN, Optimality of SPRT, Wald's fundamental identity-OC functions, SPRT for one sided hypotheses, Sample size determination- Stein's two stage procedure. [11]

References :

C.R.Rao	:	Linear Statistical Inference and its Applications
E.L.Lehmann	:	Theory of Point Estimation
T.S.Ferguson	:	Mathematical Statistics
D.Sigmund		Sequential Inference
J.Berger		Statistical Decision Theory - Foundation, Concepts & Methods
B.K.Ghosh		Sequential Tests of Statistical Hypotheses
Nitis Mukhopadhyay		Probability and Statistical Inference

Regression Analysis

Univariate and Bivariate data: Concept of Regression.
Regression with one explanatory variable: Direct, Reverse, Orthogonal and Least Absolute Deviation (LAD) regressions with applications, Weighted Least Squares technique.
Regression with several explanatory variables: Multiple linear regressions. [4]
Residual analysis: Residuals and their plots: Tests of fit of a model, Detection of Outliers. [6]
Departures from the usual assumptions: Heteroscedasticity, Autocorrelation, Multicollinearity, Non-normality- Detection and remedies, Robust regression. [11]
Model Selection and Non linear Models [4]

References :

H.Scheffe	:	The Analysis of Variance
S.R.Searle	:	Linear Models
G.A.F.Seber	:	Linear Regression Analysis
N.Giri	:	Analysis of Variance
D.D.Joshi	:	Linear Estimation & Design of Experiments
Chatterjee & Hadi		Sensitivity analysis in linear regression
Chatterjee & Price		Regression analysis by example

Distribution Theory II

Random sampling from a Multivariate normal distribution- Independence of sample mean vector and SS-SP matrix. [5]

Wishart matrix-its distribution (without derivation) and properties [7]
Applications of the distributions of correlation matrix, multiple correlation coefficient, partial correlation coefficient and regression coefficients [4]

Hotelling T^2 statistic and its application (including simultaneous confidence interval), Mahalanobis D^2 statistic. [5]

Matrix variate non-normal distributions: Gamma & Beta distributions [4]

References :

C.R.Rao	: Linear Statistical Inference and its Applications
T.W.Anderson	: Introduction to Multivariate Analysis
A.M.Khirsagar	: Multivariate Analysis
S.S.Wilks	: Mathematical Statistics
M.S.Srivastava & C.G.Khatri	: Introduction to Multivariate Statistics
R.J.Muirhead	: Aspects of Multivariate Statistical Theory

Statistical Computing I

Data Manipulation: Built-in datasets in R, read.table() and write.table() functions, Reading from a text file.
The built-in distributions in R : cdf, densities, quantiles, random samples.
Statistical Inference: One sample and two sample problems, Analysis of Variance, Goodness of fit tests.
Regression Analysis: Multiple linear regression (`lm()`) function : model specification and fitting, computing predicted values and residuals, inference. Weighted Least Squares.
Regression Diagnostics: Measures of identifying unusual observations (influence.measures(), dfbetas(), dffits(), cook.distance()…).
Transformations & Tests for Normality: Box-Cox Transformation, Q-Q plot, Shapiro-Wilk Test.

Part 2, 1st Semester

Advanced Paper 1(Section I): Survival Analysis

Concepts of lifetime, Various schemes of censoring and associated likelihoods. [4]
Estimation of survival function:
Parametric procedure: Point estimation, Scores and likelihood ratio tests for selected parametric models and confidence intervals. [5]
Distribution free procedures: Actuarial estimator, Kaplan-Meier and Nelson – Aalen estimators. [7]
Regression models: Estimation in parametric and Semi-parametric models-Cox's proportional hazard model, Time dependent covariates, Rank test. [6]
Competing risk analysis and Multivariate models. [3]

References :

D.R.Cox & D.Oakes	: Analysis of Survival Data
A.J.Gross & A.V.Clark	: Survival Distribution: Reliability Applications in the Biomedical Sciences
R.G.Miller	: Survival Analysis
P.J.Smith	: Analysis of Failure and Survival Data

J.D.Kalbfleisch & R.L.Prentiice : The Statistical Analysis of Failure Time Data
J.P.Klein & M.L.Moeschberger : Survival Analysis: Techniques for Censored and Truncated Data

Advanced Paper 2 (Section I): Advanced Survey Methodologies

The basic model, Sampling Design and sampling schemes. Hanurav's unit drawing algorithm: Inclusion probabilities of first two orders, Relation with effective sample size and variance of effective sample size. [4]

Data and estimators-linear and linear unbiased estimators of population total, Horvitz – Thompson estimator, Generalized difference and generalized regression estimators, issues in non-negative variance estimation. π PS sampling schemes of Midzuno-Sen, Brewer, Durbin and JNK Rao, Rao-Hartley-Cochran strategy. [5]

Randomised response: The Warner model: unbiased and maximum likelihood estimation. The unrelated question models methods (one and two unrelated characters)-unbiased estimation under the cases where the population in the unrelated group is known/unknown, comparison with the Warner model. [5]

Estimation for domains - the basic estimation method, ratio and regression estimators for domains. Issues in small domain estimation - synthetic estimators. [3]

Non-sampling errors and biased responses, errors in surveys, modeling observational errors, estimation of variance components, application to longitudinal studies (repetitive surveys). [4]

Adaptive sampling for rare and elusive population [4]

References :

C.M.Cassel, C.E.Sarndal& J.H.Wretman. :Foundations of Inference in survey Sampling
A.Chaudhuri & R.Mukerjee :Randomized Response - theory and techniques
A.Chaudhuri & J.W.E.Vos :United Theory and Strategies of Survey Sampling
A.S.Hedayat & B.K.Sinha :Design and Inference in Finite Population Sampling
P.Mukhopadhyay :Inferential Problems in Survey Sampling
C.E.Sarndal., B.Swensson& J.Wretman :Model assisted Survey Sampling
J.N.K.Rao Small Area Estimation

Advanced Paper 3(Section I): Operations Research

Definition and Scope of Operations Research: phases in Operation Research, models and their solutions, decision-making under uncertainty and risk, use of different criteria, sensitivity analysis.

Decision-making in the face of competition, two-person games, pure and mixed strategies, existence of solution and uniqueness of value in zero-sum games, finding solutions in mixed strategy games.

Analytical structure of inventory problems, 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.
Queuing models – specification and effectiveness measures. Steady-state solutions of M/M/1 and M/M/c models with associated distributions of queuelength and waiting time. M/G/1 queue and Pollazcek-Khinchine result.
Network Flow Models, minimum spanning tree, shortest path, mincut-maxflow, CPM and PERT using network flow. Traveling salesman Problem.
Replacement theory, sequencing. [25]

References :

H.A.Taha	: Operational Research
F.S.Hillier & G.J.Leiberman	: Introduction to Operations Research
Kanti Swarup, P.K.Gupta & M.M.Singh	: Operations Research
D.T.Philips, A.Ravindran & J.Solberg	: Operations Research
C.W.Churchman, R.L.Ackoff & E.L.Arnoff	: Introduction to Operations Research
T.M.Starr & D.W. Miller	: Inventory Control - Theory & Practice
L.Kleinrock	: Queueing Systems
Sasieni,Yaspan & Friedman	: Operations Research
Sasieni & Achoff	: Operations Research

Statistical Inference III

Large Sample Inference: Large sample properties of estimators: Consistency, Efficiency and Asymptotic Normality-CAN and BAN estimators. [5]
Maximum likelihood method of estimation- Large sample properties. [8]
Likelihood ratio, Rao and Wald tests for simple and composite hypotheses- properties and asymptotic distribution of test criteria in the simple hypothesis case. [7]

Decision Theory: Loss, Decision rules and Risk function, Admissibility of decision rules, Bayes and Minimax rules. [10]

Nonparametric Methods: U-statistics- Definition and Asymptotic properties.
Nonparametric tests: Single sample Problems: Location, Location-cum-symmetry, and Goodness-of-fit problems.
Two-sample Problems : Location, Scale and Homogeneity problems.
Multi-sample location problem.
Friedman Two-way Analysis of variance problem.
Bivariate association problem, Cochran Q-test for dependent samples.
Nonparametric Interval Estimation.
Concept of Asymptotic Relative Efficiency. [20]

References :

J.D.Gibbons :Nonparametric Inference

T.P. Hettmansperger :Statistical Inference based on ranks

C.R.Rao :Linear Statistical Inference and its Applications

E.L.Lehmann :Theory of Point Estimation

R.J.Serfling :Approximation Theorems of Mathematical Statistics

E.L.Lehmann :Large Sample Theory

Stochastic Process

Stochastic Process: Markov chain with finite state space and countable state space, Classification of states, Chapman-Kolmogorov equation, Calculation of n-step transition probability matrix and its limit, Stationary distribution of Markov chain, Random walk and Gambler's ruin problem, Reversibility. [14]

Discrete state space continuous time Markov chains, Poisson process, Pure birth process, Pure death process, Birth and death processes. [7]

Renewal theory: Elementary Renewal theorem, Stopping time, Statement and uses of Key Renewal theorem [7]

Branching process, Galton-Watson Branching Process, Probability of ultimate extinction and distribution of population size [5]

Brownian motion [2]

Time Series Analysis: Stationary Time Series, Autocorrelation and partial autocorrelation functions, Correlogram Analysis. [6]

Forecasting Procedures-Box-Jenkins [4]

Spectral analysis-Periodogram [5]

References :

S.Karlin and H.M.Taylor :A First Course in Stochastic Processes

J Medhi :Stochastic Process

D.R.Cox :Renewal Theory

S.Ross :Stochastic Process

Basu A.K. :Stochastic Process

Hoel P.G., Port S.C. and Stone C.J :An Introduction to Stochastic Process

C.Chatfield :The Analysis of Time Series - An Introduction

G.E.P.Box, G.M.Jenkins & G.C.Reinsel :Time Series Analysis - Forecasting and Control

A.Pankratz :Forecasting with Univariate Box-Jenkins Model

G. Jancek and L. Swift :Time Series - Forecasting, Simulation, Applications

Statistical Computing I

Advanced Computing with C: Simulating multivariate distributions, Search methods – Binary Search, Breadth First Search using C

Advanced Computing with R:

Creating user defined functions: Conditional statements, loops, arrays.

Numerical optimization: Solution of numerical equations(one and two unknowns)-Maximum Likelihood Estimates, Nonlinear regression(nls() and nlm() functions).
Useful contributed packages: `Hmisc` (sample size, power calculations etc), `mvtnorm` (multivariate normal and t distributions).
Numerical Integration: Numerical evaluation of probabilities involving one and two random variables, Comparison of Power curves.
Simulations : Simulating distributions of standard test statistics and power, Evaluation of multiple integrals.
Interface with programming languages: Interface with C.

Part 2, 2nd Semester

Advanced Paper 1(Section –II): Clinical Trials

Introduction and basic study designs,
Randomized clinical trials: Ethics in clinical trials, Sample size determination [6]
Randomization for balancing treatment assignments (random allocation rule, truncated binomial design, biased coin designs, urn models; corresponding bias and inference) [10]
Response Adaptive designs for binary responses (play-the-winner and randomized-play -the –winner rules), Group sequential designs, Reporting and Interpretation of results. [9]

References :

S.Piantadosi :Clinical Trials - A Methodologic Perspective
B.S.Everitt and A.Pickles :Statistical Aspects of Design & Analysis of Clinical Trials
S.J.Pocock :Clinical Trials
J.Whitehead :The Design and Analysis of Sequential Clinical

Advanced Paper 2(Section-II) : Model-Based Inference in Survey Sampling

Inference under fixed population model: sufficiency and likelihood [2]
Choosing good sampling strategy [2]
Nonexistence theorem of Godambe and Joshi [3]
Inference under super population model [4]
Prediction approach [4]

Asymptotic approach- asymptotic design unbiasedness and consistency [3]
Model based inference in small area estimation – Fay - Herriot model [4]
Bayesian procedures in survey sampling [3]

References :

C.M.Cassel, C.E.Sarndal.& J.H.Wretman : Foundations of Inference in **S**urvey Sampling
A.Chaudhuri & H.Stenger : Survey **S**ampling—Theory and Methods
A.S.Hedayat & B.K.Sinha : Design and Inference in Finite Population Sampling
C.E.Sarndal., B.Swensson& J.Wretman : Model Assisted **S**urvey Sampling
J.N.K.Rao Small **A**rea Estimation

Advanced Paper 3(Section-II): **Optimization**

Generalized L.P.P. Bounded variables, decomposition principle of Dantizg and Wolfe. Transportation problem.
Unconstrained Optimization, Optimality Conditions, first-order, second-order necessary sufficiency under convexity. Algorithms for Univariate Optimization: Bisection, Newton, Safeguarded Newton, Golden section search, Fibonacci rates of convergence.
Integer programming – integer linear and mixed integer linear programming problems, Gomery's cutting plane method, Branch and Bound method. Binary Programming – Bala's algorithm ISI.
Non-linear programming –optimization with equality & inequality constraints: Details of Karush-Kuhn-Tucker theory, Quadratic Programming – Wolfe's algorithm and Beale's algorithm. [25]

References :

G.Hadley : Non-linear and Dynamic Programming
K.G.Murthy : Linear and Combinatorial Programming
P.Whittle : Optimization under Constraints
- Theory and Applications of Non-linear Programming
S.S.Vajda : Probabilistic Programming
N.S.Kambo : Mathematical Programming Techniques
S.S.Rao : Optimization - Theory and Applications
K.V.Mittal : Optimization Methods

Data Analysis

Categorical Data Analysis: Categorical Response Data: Nominal/ Ordinal Distinction, Probability Distributions for Categorical Data-Binomial& Multinomial Distributions.
Inference for a proportion: Wald, Score, and Likelihood-Ratio Inference for Binomial Parameter [3]
Contingency Tables**:** Probability Structure for Contingency Tables: Joint, Marginal, and Conditional Probabilities, Relative risk and odds ratio-properties.

Measures of association and tests for independence in contingency tables: Nominal-Nominal, Ordinal – Ordinal and Nominal–Ordinal Tables.
Exact Inference for Small Samples- Fisher's Exact Test for 2×2 Tables. [6]
Association in more than two-way classified data: Partial association, Conditional Versus Marginal Associations- Simpson's Paradox, Conditional and Marginal Odds, log-odds ratio and its distribution, Independence-Conditional Versus Marginal. [6]
Generalized Linear Models: Introduction, Components, Goodness of fit measures-residuals and deviance. Inference for Generalized Linear Models [5]
Applications to binary, count and polytomous data, Over dispersion. [4]
Marginal, Conditional and quasi likelihood functions (simple ideas) [2]
Longitudinal Data Analysis: Introduction with motivation, Exploring longitudinal Data with some specific dependence structure [5]
Missing data mechanism: Inference procedures for data with missing values- E-M algorithms. [4]
Re-sampling Techniques: Introduction to Jackknife and Bootstrap – methods for estimating bias ,standard error and distribution function based on i.i.d. random variables. Standard examples. Justification of the methods in i.i.d. set-up. [12]
Bootstrap confidence intervals [3]

References :

A.Agresti	: Categorical Data Analysis
P.McCullagh & N.Nelder	: Generalized Linear Models
R.J.A Little and D.B.Rubin	: Statistical analysis with Missing data
B. Efron	: The Jackknife, the Bootstrap and other Sampling Plans
B.Efron	: Bootstrap methods - another look at jackknife
B.Efron & R.J.Tibshirani	: An Introduction to the Bootstrap
J.Shao & D.Tu	: The Jackknife and Bootstrap

Applied Multivariate Analysis

Principal Components and Canonical correlation Analysis	[7]
Discriminant Analysis and Classification Problems	[6]
Factor Analysis	[7]
Cluster Analysis	[5]

References :

T.W.Anderson	: An Introduction to Multivariate Statistical Analysis
R.A.Johnson. & D.W.Wichern	: Applied Multivariate Statistical Analysis
A.M.Khirsagar	: Multivariate Analysis
D.F.Morrison	: Multivariate Statistical Methods
R.J.Muirhead	: Aspects of Multivariate Statistical Theory
G.A.F.Seber	: Multivariate Observations