NEP

Two- Year and One-Year

Postgraduate Programmes

in

Statistics

[With effect from 2026]

Department of Statistics,

West Bengal State University.

(Coordinator)

Head of the Department
Department of Statistics
West Bengal State University

Overview of the courses
2-Year Postgraduate programme in Statistics*

Semester I			Credits	Marks	Total
STS2PCOR01T	Departmental 1	Mathematical Methods	4	50	Total Credits =22 Total marks = 300
STS2PCOR02T	Departmental 2	Probability Theory	4	50	
STS2PCOR03T	Departmental 3	Descriptive Statistics & Regression Analysis	4	50	
STS2PCOR04T	Departmental 4	Sampling Distributions & Statistical Inference I	4	50	
STS2PCOR05M	Departmental 5	Introduction to AI & Lab I	4	50	
STS2PAEC01P	AEC	R Programming	2	50	
Semester II					
STS2PCOR06T	Departmental 6	Multivariate Distribution Theory & Large Sample Inference	4	50	Total Credits =20 Total marks = 250
STS2PCOR07T	Departmental 7	Linear models & Statistical Inference II	4	50	
STS2PCOR08T	Departmental 8	Survey Sampling & Design of Experiments	4	50	
STS2PCOR09T	Departmental 9	Advanced Regression Analysis	4	50	
STS2PCOR10M	Departmental 10	Internship and Lab II	4	50	
Semester III					
STS2PCOR11T	Departmental 11	Stochastic Process & Time Series Analysis	4	50	Total Credits =22 Total marks = 300
STS2PDSE01T	Departmental 12 DSE1	Advanced Sample Survey / Econometrics & Financial Statistics	4	50	
STS2PCOR12T	Departmental 13	Nonparametric Methods & Advanced Design of Experiments	4	50	
STS2PCOR13P	Departmental 14	Python Programming I and Advanced Lab I	4	50	
STS2PCOR14M	Departmental 15	Big Data Analytics	4	50	
STS2PSEC01M	SEC	Optimization Techniques	2	50	
Semester IV					
STS2PCOR15T	Departmental 16	Decision Theory & Bayesian Inference	4	50	Total Credits =24 Total marks = 300
STS2PCOR16T	Departmental 17	Data Analytic Methods & Categorical Data Analysis	4	50	
STS2PDSE02T	Departmental 18 DSE 2	Biostatistics / Industrial Statistics	4	50	
STS2PCOR17T	Departmental 19	Applied Multivariate Analysis	4	50	
STS2PCOR18P	Departmental 20	Python Programming II & Advanced Lab II	4	50	
STS2PCOR19M	Departmental 21	Project Work & Seminar Presentation	4	50	

* Students who shall join the 2-Year Post-graduate course may exit after completion of one year with award of "Postgraduate Diploma" on Statistics.

Overview of the courses
1-Year Post-graduate programme in Statistics

Semester I			Credits	Marks	Total
STS1PCOR01T	Departmental 1	Stochastic Process & Time Series Analysis	4	50	Total Credits =22 Total marks = 300
STS1PDSE01T	Departmental 2 DSE1	Advanced Sample Survey / Econometrics & Financial Statistics	4	50	
STS1PCOR02T	Departmental 3	Nonparametric Methods & Advanced Design of Experiments	4	50	
STS1PCOR03P	Departmental 4	Python Programming I and Advanced Lab I	4	50	
STS1PCOR04M	Departmental 5	Big Data Analytics	4	50	
STS1PSEC01M	SEC	Optimization Techniques	2	50	
Semester II					
STS1PCOR05T	Departmental 6	Decision Theory & Bayesian Inference	4	50	Total Credits =24 Total marks = 300
STS1PCOR06T	Departmental 7	Data Analytic Methods & Categorical Data Analysis	4	50	
STS1PDSE02T	Departmental 8 DSE 2	Biostatistics / Industrial Statistics	4	50	
STS1PCOR07T	Departmental 9	Applied Multivariate Analysis		50	
STS1PCOR08P	Departmental 10	Python Programming II & Advanced Lab II	4	50	
STS1PCOR09M	Departmental 11	Project Work & Seminar Presentation	4	50	

<u>**Syllabus for 2-Year and 1-Year M.Sc. Programme in Statistics**</u>

Semester I (2-Year M.Sc. in Statistics)

STS2PCOR01T: Mathematical Methods [50 marks]

Real Analysis
Real number system, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass property, Heine-Borel property & its applications. [14]

Sequences and Series of functions: pointwise convergence, uniform convergence, absolute convergence. Some tests of convergence. Continuity, uniform continuity, differentiability of univariate and multivariate functions. Mean value Theorem. [14]

Reimann integral and its properties. Reimann-Stieltjes integral. Review of sequence and series of functions. Uniform convergence: term by term differentiation and integration Power series. Taylor series expansion. [10]

Linear Algebra
Vector spaces with real field. Basis dimension of vector space. Orthogonal vectors, Gram-Schmidt orthogonalization. [2]

Linear transformation of matrices. Matrix operations. Elementary matrices and their uses, Echlon matrix. Rank of a matrix and related results. Determinants. Inverse of a matrix. [3]

System of linear equations: homogenous and non-homogenous system. Generalized inverse: Moore-Penrose. [3]

Idempotent matrices and its properties. Characteristic roots and vectors. Quadratic forms and canonical reduction. Singular value decomposition (Statement only) [4]

References
M. Apostal. : Mathematical analysis.
R. Rudin. : Principles of Mathematical analysis.
R. R. Goldberg. : Methods of real analysis.
R. G. Bartle, & D.R. Sherbert. : Introduction to real analysis.
S. K. Mapa. : Introduction to real analysis.
A. M. Goon. : Vectors and matrices.
G. Hadley. : Linear algebra.
F. E. Graybill. : Introduction to Matrices with Applications in Statistics.
C. R. Rao. : Linear Statistical Inference and Its Applications.
S. R. Searle. : Matrix Algebra Useful for Statistics.

STS2PCOR02T: Probability [50 marks]

Random Variables: Definition of discrete and continuous random variables. Cumulative distribution function and its properties, probability mass function and probability density function. Expectation and moments, Dispersion, Skewness, Kurtosis and Quantiles. [5]

Bivariate probability distributions. Marginal and conditional distributions. Independence. Conditional moments. [3]
Correlation and Regression. Generating Functions : probability generating function and moment generating function in univariate and bivariate cases. [5]

Probability Inequalities : Chebyshev's lemma, Markov's & Chebyshev's inequalities. Some common univariate distributions. Bivariate Normal distributions and its properties. [6]

Limit Theorems: Convergence in distribution: De-Moivre-Laplace limit theorem and Normal approximation to the Poisson distribution. [4]

Generating functions and Characteristic functions [2]

Sigma fields in probabily. Borel sigma field. Measures and its properties. Probability as a measure. Measurable functions. Random variable, Integration of a measurable functions. [5]

Sequence of measurable functions: Monotone convergence theorem, Fatou's lemma and Dominated convergence theorem (Statements only) and their probabilistic aspects. [5]

Distribution functions [3]

Independence: Borel-Cantelli Lemma. Sequence of random variables. Different modes of convergence of a sequence of random variables-inter-relations. Weak and Strong laws of large numbers: related results. Kolmogorov's inequality. [8]

Central limit theorems & its applications. [4]

References
K. L. Chung — Elementary Probability Theory with Stochastic Processes.
W. Feller — An Introduction to Probability Theory and Its Applications, Vol. 1.
A. M. Goon, M. K. Gupta & B. DasGupta — An Outline of Statistical Theory, Vol. 1.
V. K. Rohatgi & M. E. Saleh — An Introduction to Probability and Statistics.
J. Pitman — Probability.
D. Stirzaker — Elementary Probability.
J. F. C. Kingman & S. J. Taylor — Introduction to Measure and Probability.
P. Billingsley — Probability and Measure.
R. Ash — Real Analysis and Probability.
A. Gut — An Intermediate Course in Probability.
R. R. Bhat — Modern Probability Theory.
J. Jacod & P. Protter — Probability Essentials.
K. B. Athreya & S. N. Lahiri — Measure Theory and Probability.
A. K. Basu — Measure Theory and Probability.
J. V. Uspensky — Introduction to Mathematical Probability and Its Application.

STS2PCOR03T: Descriptive Statistics & Regression Analysis [50 marks]

Descriptive Statistics

Introduction to Descriptive statistics. Different types of data. Graphical representations. Univariate data : Different measures of location, dispersion, Relative dispersions, Skewness and kurtosis, Moments and Quantiles. Stem-and-leaf plot. Histogram and density plot. Box plot. [10]

Gini's coefficient and Lorenz curve. [3]

Bivariate data : Scatter diagram, Correlation coefficient and its properties. Correlation ratio, Correlation Index. Intraclass correlation with equal and unequal group sizes. Some multivariate plots and its' interpretations: Time plot and Star plot. [12]

Regression Analysis
Simple linear regression and related results. Multiple linear regression. Multiple correlation and partial correlation and their properties. [7]

Heterogeneity and analysis of variance (ANOVA) and covariance (ANCOVA). Linear hypothesis and orthogonal splitting of total variance. Applications of the ANOVA technique: one-way classified data, two-way classified data with number of observations per cell. [8]
Testing simple regression coefficients, correlation ratio, linearity of simple regression, and multiple correlation and partial correlation coefficients. [10]

References
A. M. Goon, M. K. Gupta, & B. DasGupta: Fundamentals of Statistics (Vol. 1);
G. W. Snedecor & W. G. Cochran: Statistical Methods
J. W. Tukey: Exploratory Data Analysis
N. R. Draper & H. Smith: Applied Regression Analysis
D. G. Montgomery, E. A. Peck, & G. G. Vining: Introduction to Linear Regression Analysis
Debasis Sengupta & S. Rao Jammalamadaka. : Linear Models and Regression: An Integrated Approach.
Debasis Sengupta & S. Rao Jammalamadaka. : Linear Models and Regression With R: An Integrated Approach.
H. Sheffe : The analysis of variance.
J. J. Faraway. : Linear models with R.
X. Yan & X. G. Su. : Linear Regression Analysis: Theory and Computing.

STS2PCOR04T: Sampling Distributions & Statistical Inference I [50 marks]

Sampling Distributions
Univariate distributions: Binomial, Poisson, Negative Binomial, Exponential, Normal, Log-normal and their properties. [7]

Concepts of random sampling. Sampling distribution of sample proportions, Sampling distribution of a statistics and standard errors. Some standard sampling distributions: Chi-square distribution, Derivation of the sampling distribution of sample mean and variance for a normal population, Student's and Fisher's t-distributions, Snedecor's F-distribution, Relationship between t, F and Chi-square distributions. [13]

Order Statistics: Introduction, distribution of the order statistic, smallest and largest order statistics. Joint distribution of order statistics, distribution of sample median and sample range. [5]

Statistical Inference I
Concepts of Statistical Inference. A general overview: Estimation, Testing, and Confidence interval

estimation. [5]

Data reduction: Sufficiency and minimal sufficiency, Completeness, Bounded completeness and Ancillary Statistic. Exponential family of distribution. [10]

Point Estimation*:* Concepts of point estimation. Requirement of a good estimator: notion of mean square errors, Unbiasedness and minimum variance. Methods for Minimum variance unbiased estimators. Cramer-Rao and Bhattacharaya system of lower bounds. Rao-Blackwell and Lehmann-Scheffe theorems. [10]

References

V. K. Rohatgi, & A. K. Saleh. : An Introduction to Probability and Statistics.
R. V. Hogg, & E. A. : A Brief Course in Mathematical Statistics.
A.M. Mood, F.A. Graybill, & D.C. : Introduction to the Theory of Statistics.
R. V. Hogg, & A.T. Craig. : Introduction to Mathematical Statistics.
G. Casella , & R. L. Berger. : Statistical Inference.
S. S. Wilks. : Mathematical Statistics.
S. Zacks. : Theory of statistical inference.
E. L. Lehmann & G. Casella: Theory of point estimation.

STS2PCOR05M: Introduction to AI & Lab I [50 marks]

Introduction to AI

Introduction & Systematic Search: Definitions and scope of AI; the Turing Test. AI agents and agent architectures; problem formulation: states, initial state, actions, transition model, goal test, path cost. Uninformed (systematic) search algorithms: Breadth-First Search (BFS) — queue-based, finds shortest path (in terms of number of steps), completeness and time/space complexity; Depth-First Search (DFS) — stack-based, memory-efficient, issues with completeness and optimality. (8)

Heuristics & Local Optimization: Informed search and heuristic functions, admissibility and consistency. A* search: evaluation function f(n)=g(n)+h(n)f(n)=g(n)+h(n), properties, optimality and complexity. Local search methods: Hill Climbing, advantages and problems (local maxima, plateaus, ridges), techniques to mitigate (random restarts, simulated annealing). Evolutionary methods: Genetic Algorithms — representation, selection, crossover, mutation, fitness functions, convergence. (10)

Constraint Satisfaction Problems (CSP): CSP fundamentals: variables, domains, constraints, solutions. Backtracking search with inference techniques and pruning strategies. Applications in experimental design and survey sampling. (3)

Handling Uncertainty: Sources of uncertainty: noise, incomplete information, stochastic effects. Bayes' Theorem and its use in updating beliefs for agent decisions. Decision making under uncertainty: expected value as metric, utility and simple decision-theoretic examples. (4)

Lab I

Practical exercises based on Linear algebra, Descriptive Statistics & Regression Analysis I and Statistical Inference I. (25)

References

S. Russell & P. Norvig: Artificial Intelligence: A Modern Approach.
R. E. Knight & S. B. Nair: Artificial Intelligence.
David Barber. : Bayesian Reasoning and Machine Learning.

STS2PAEC01P: R Programming [50 marks]

Introduction to R : Installing R and Rstudio. Basic operations. Running R script. R notebook. 'Input from' and 'output to'. Accessing systems. R as a scientific calculator. Scripting: Basic rules, operations and relational. Looping and Iterating. Conditional loops.
Graphics in R: 2D, 3D plots: scatter, line, bar, histogram, pie, etc. plot functions: legend, text, equation and color, par function and multiple /multi-paneled plots.

Core data structures: vectors, matrices, arrays, lists, and data frames; creation, indexing, and basic operations. String handling and manipulation: constructing and modifying character vectors, substrings, pattern matching, insertion, replacement, and concatenation. Data manipulation: working with built-in datasets; importing data from external sources (e.g., text/CSV files, spreadsheets); basic data cleaning and transformation. Regular expressions: pattern specification and use with R string functions for searching, matching, and replacing text. Functions in R: built-in functions, binding values to symbols, writing user-defined functions, lazy evaluation, and scoping rules (lexical vs dynamic scoping). Environments: concept, environment hierarchy, and their role in scoping and evaluation.

Modern R syntax features: use of pipes for readable workflows and an introduction to traits/object-like behavior where relevant.

Matrix calculations using R: Vectors and matrices. Basic operations on vector and matrices . Solution of linear equations. Eigenvalues and Eigenvectors of a square symmetric matrix. Spectral Decomposition, LU,QR, Choleski, and Singular Value Decomposition (SVD). Moore-Penrose Generalized inverse. Finding a basis, orthonormalisation and finding rank.

Linear models : the lm function: ANOVA/ANCOVA/regression, models, the summary function, goodness of fit measures, predicted values and residuals; the ANOVA table, confidence intervals and confidence ellipsoids. Multiple testing.

Programming in R : Advanced graphics, Optimization technique, Numerical Integration and differentiation, Random number generations and Simulation, and Monte Carlo methods.

References

G. Grolemund. : Hands-on Programming with R: Write Your Own Functions and Simulations.
J. Wickham & G. Grolemund. : R for Data Science.
T.M. Davies: The Book of R: A First Course in Programming and Statistics.
J. Fox & S. Weisberg. : An R Companion to Applied Regression.
N. Fieller. : Basics of Matrix Algebra for Statistics with R.
J.F. Monahan. : A Primer on Linear Models with R. CRC Press.
M.L. Rizzo : Statistical Computing with R. CRC Pres
J. Albert & M. L. Rizzo. : R by Example.
M. J. Crawley: The R Book.

N. Matloff. : The art of R Programming
A. de Vries, & J. Meys. : R for dummies.
P. Dalgaard. : Introductory statistics with R.
P. Murrell. : R graphics.
J. Maindonald, & W. J. Braun. : Data analysis and graphics using R: An example-based approach.

Semester II (2-Year M.Sc. in Statistics)

STS2PCOR06T: Multivariate Distribution Theory & Large Sample Inference [50 marks]

Multivariate Distribution Theory

General discussion on multivariate distributions. Multinomial distribution and its properties. Multivariate normal distribution and related results. Distribution of quadratic forms, Cochran's theorem. [12]

Random sampling from a multivariate normal distribution: Wishart distribution and its properties. Hotelling T-square statistics: its distribution and related results. Mahalanobis D-square statistics. [13]

Large Sample Inference

Asymptotic Methods: Large sample properties of estimators: Consistency, Efficiency and Asymptotic Normality-CAN and BAN estimators. [8]

Method of moments estimator, Maximum likelihood estimator (MLE) - Large sample properties. Efficient estimator. [8]

Likelihood ratio, Rao and Wald tests for simple and composite hypotheses- properties and asymptotic distribution of test criteria in the simple hypothesis case. [9]

References

C. R. Rao. : Linear Statistical Inference and Its Applications.
T. W. Anderson. : Introduction to Multivariate Analysis.
A. M. Khirsagar. : Multivariate Analysis.
R. J. Muirhead. : Aspects of Multivariate Statistical Theory.
G. A. F. Seber. : Multivariate Observations.
M. Bioodeau, & D. Brenner. : Theory of Multivariate Statistics.
A. M. Goon, M. K. Gupta, & B. Dasgupta. : An Outline of Statistical Theory (Vol. I).
V. K. Rohatgi, & A. K. Saleh. : An Introduction to Probability and Statistics.
E. L. Lehmann. : Elements of large-sample theory.
T. S. Ferguson. : A course in large sample theory.
P. K. Sen, & Singer. : Large sample methods in statistics: An introduction with applications.
A. Dasgupta. : Asymptotic theory of statistics and probability.
R. A. Johnson, & D. W. Wichern. : Applied multivariate statistical analysis.
A. V. Rencher, & W. F. Christensen. : Methods of multivariate analysis.
T. W. Anderson.: An introduction to multivariate statistical analysis.
G. A. F. Seber.: Multivariate observations.
R. J. Muirhead. : Aspects of multivariate statistical theory.
M. Bilodeau, & D. Brenner. : Theory of multivariate statistics.
B. Everitt & T. Hothorn. : An introduction applied multivariate analysis with R.

STS2PCOR07T: Linear Models & Statistical Inference II [50 marks]

Linear Models

Gauss-Markov model. Estimable functions. Best linear unbiased estimator (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. [8]

Analysis of variance. Analysis of covariance (Example only). Introduction to random and mixed effect models (balanced case: example only). [7]

Statistical Inference II

Testing of hypotheses: Nonrandomized and Randomized tests, Critical function, Power function. Most Powerful (MP) Tests: Neyman-Pearson Lemma (Existence, Sufficiency and Necessity). Uniformly most powerful (UMP) tests: simple problems for exponential and pitman families of distributions. Enlargement technique for testing a composite null against a composite alternative. UMP tests for monotone likelihood ratio (MLR) families. Generalised Neyman-Pearson Lemma: uniformly most powerful unbiased (UMPU) tests for one parameter exponential families. Ideas of similar tests. [15]

Sequential analysis: Sequential Probability ratio test (SPRT). Wald's equation. Optimality of SPRT. Wald's fundamental identity. SPRT of one sided test. [7]

Confidence interval estimation: Relation with hypothesis testing. Optimum parametric confidence intervals. [3]

References

H. Scheffe. : Analysis of variance.
S. R. Searle. : Linear models.
G. A. F. Seber, & A. J. Lee. : Linear regression analysis.
N. Giri. : Analysis of variance.
C. R. Rao. : Linear statistical inference and its applications.
R. B. Bapat. : Linear algebra and linear models.
A. M. Kshirsagar.: A course in linear models.
B. R. Clarke.: Linear models: The theory and application of analysis of variance.
B. Jorgensen.: The theory of Linear models
M. H. J. Gruber. : Matrix algebra for linear models.
E. L. Lehmann, & J. P. Romano. : Testing statistical hypotheses.
G. C. Casella, & R. L. Berger. Statistical inference.
S. Zacks. : Theory of statistical inference.
V. K. Rohatgi, & Md. E. Saleh. : An Introduction to probability and statistics.
R. W. Keener. : Theoretical statistics: Topics for a core course.
P. J. Bickel, & K. A. Doksum. : Mathematical statistics: basic ideas and selected topics (vol.1).

STS2PCOR08T: Survey Sampling & Design of Experiments [50 marks]

Survey Sampling
Probability sampling from a finite population. Basic sampling schemes–Unequal probability sampling with and without replacement, Related estimators of population total/mean, their variances and variance estimators – Mean per distinct unit in simple random with replacement sampling, Hansen Hurvitz estimator in unequal probability sampling with replacement, Des Raj and Murthy's estimator (for sample of size two) in unequal probability sampling without replacement. [9]

Stratified sampling – The allocation scheme & the basic idea of optimal allocation, construction of strata. Basic ideas of Ratio, Product, Difference and Regression estimators. Unbiased Ratio type estimators. Hartley – Ross estimator in simple random sampling. [6]

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. Double sampling for stratification. Double sampling ratio and regression estimators. [10]

Design of Experiments
Basic principles of experimental design: randomization, replication, and local control. Uniformity trials. Shapes and sizes of plots and blocks. [4]

Standard designs and their analyses : completely randomised design (CRD), randomised block design (RBD), latin square design (LSD), Quantitate ideas of split plot design, and strip arrangements. Comparison of efficiencies. Applications of the techniques of analysis of variance to the analysis of the above designs, Missing plot techniques in CRD, RBD and LSD. [9]

General block designs and its information matrix. Concepts of connectedness, orthogonality and balance. Resolvable designs. Properties of BIB designs. Designs derived from BIB designs. Intrablock analysis of orthogonal (CRD, RBD, LSD) and non-orthogonal designs (Balanced incomplete block design. [12]

References
A. Chaudhuri & S. Pal. : A comprehensive textbook of sample surveys.
W. G. Cochran. : Sampling techniques.
Des Raj. : Sampling theory.
A. S. Hedayat & B. K. Sinha. : Design & inference in finite population sampling.
P. Mukhopadhyay. : Theory & methods of survey sampling.
P. S. Levy, & S. Lemeshow. : Sampling of populations: Methods and applications.
S. K. Thompson. : Sampling.
A. Chaudhuri. : Essentials of survey sampling.
A. Chaudhuri, & H. Stenger. : Survey sampling: Theory and methods.
A. M. Dean, & D. Voss : Design and analysis of experiments.
O. Kempthrone. : The design and analysis of experiments.
M. N. Das, & N. C. Giri. : Design and analysis of experiments.
D. C. Montgomery. : Design and analysis of experiments.
W. G. Cochran, G. M. Cox. : Experimental designs.
W. T. Federer. : Experimental designs: Theory and application
M. C. Chakraborty. : Mathematics of design and analysis of experiments.
A. Dey. : Theory of block designs.
G. A. Milliken, & D.A. Johnson. : Analysis of messy data Vol. 1: Designed experiments.

STS2PCOR09T: Advanced Regression Analysis [50 marks]

Weighted least squares, Box-Cox and other transformation methods. Dummy variables and its applications. [7]

Tests of fit of a model. Detection of outliers. Residual analysis: residuals and their plots. Departures from the usual assumptions: heteroscedasticity, autocorrelation, multicollinearity, Non-normality- detection and remedies. [15]

Model selection. [3]

Generalized Linear Models (GLM): Introduction, components, goodness of fit measures-residuals and deviance. [5]

Inference for GLM. Application to regression modeling for binary response, count response and ordinal / nominal response. Over dispersion. Marginal, conditional and quasi likelihood functions. [10]

Robust regression: Effects of outliers, LAD regression, M-estimation, LTS regression, S-estimation, and data analytic examples. [10]

References

A. Sen, & M. Srivastava. : Regression analysis: Theory, methods, and applications.
S. Chatterjee, & A. S. Hadi. : Sensitivity analysis in linear regression.
S. Chatterjee, & A. S. Hadi. : Regression analysis by example.
S. Weisberg. : Applied linear regression.
J. Fox. : Regression diagnostics: An introduction.
D. A. Belsley, E. Kuh, & R. E. Welsch. : regression Diagnostics: Identifying influential data and Sources of collinearity.
N. Giri. : Linear Estimation & design of experiments.
D. N. Gujarati. : Basic econometrics.
D. N. Gujrai, & D. Porter. : Basic econometrics.
J. M. Wooldeidge.: Introductory econometrics: A modern approach.
Debasis Sengupta & S. Rao Jammalamadaka .: Linear Models: An Integrated Approach.
Debasis Sengupta & S. Rao Jammalamadaka.: Linear Models and Regression With R: An Integrated Approach.
P. McCullagh, & J. L. Nelder. : Generalized linear models.
A. Dobson, & A. Barnett. : An introduction to generalized linear models.
J. K. Lindasy. : Applying generalized linear models.
A. Agresti. : Foundations of linear and generalized linear models.
D. W. Hosmer, S. Lemeshow : Applied logistic regression.
C. E. McCullagh, S. R. Searle, & J. M. Neuhaus.: Generalized, linear, and mixed models.
J. J. Faraway. : Linear models with R.
J. J. Faraway. : Extending the linear models with R.
R. A. Marona, R. D. Martin, & V. Yohai. : Robust statistics: Theory and methods.
F. R. Hampel, E. M. Ronchetti, P. J. Rousseeuw, & W. A. Stahel. : Robust statistics: The approach based on influence functions.
P. J. Huber. : Robust Statistics.
A. M. Leroy, & P. Rousseeuw. : Robust regression and outlier detection.
R. A. Marona, D. Martin, V. J. Yohai., & M. Salibian-Barrera : Robust statistics: Theory and methods (with R).

STS2PCOR10M: Internship & Lab II [50 marks]

Internship

The internship is preferably supervised by the faculty from Higher Education Institutes. Alternatively, teachers from the department, or by an individual teacher from the department can supervise the internship. It consists of a report and a presentation. The internship period runs from the third week of June to the first week of July (three weeks). (25)

Lab II
Practical exercises based on Multivariate distribution theory, Large sample inference, Linear models, Statistical inference II, Survey sampling, Design of experiments and Advanced regression analysis. (25)

Semester III (2-Year M.Sc. in Statistics) / Semester I (1-Year M.Sc. in Statistics)

STS2PCOR11T/ STS1PCOR01T: Stochastic Process & Time Series Analysis [50 marks]

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 and reversibility. [12]

Discrete state space continuous time Markov chains, Poisson process. [6]

Renewal theory: Elementary Renewal theorem, Stopping time, Statement and uses of Key Renewal theorem. [10]

Concept of Martingles [2]

Time Series Analysis
Elements of time series: Introduction to time series data and its applications to various fields. Modeling of time series as deterministic functions of iid terms: different components and decomposition. Estimation of trends and seasonal components. Notions of multiplicative models. [4]

Stationary Time Series, linear process, causality and invertibility, properties of linear stationary process, autocovariance function (ACVF) and partial autocorrelation function (PACF), methods of finding ACVF, ARMA process as particular case. [6]

Forecasting a time series, Best linear unbiased predictor. Yule-walker equations for finding predictors for ARMA process, Box-Jenkins models, Test for Unit roots. [5]

Non-stationary process: ARIMA and SARIMA. [2]

Volatility: ARCH and GARCH model. [3]

References

S. Karlin, & H. M. Taylor. : A first course in stochastic processes.
S. Ross. : Stochastic process.
J. Medhi. : Stochastic process.
A. K. Basu. : Stochastic process.
C. Chatfield. : The analysis of time series: An introduction.
M. G. Kendall. : Time series.
G. E. P. Box, G. M. Jenkins, & G. C. Reinsel. : Time series analysis: Forecasting and control.
P. J. Brockwell, & R. A. Davis. : Introduction to time series and forecasting.
P. J. Brockwell, & R. A. Davis. : Time series: Theory and methods.
R. H. Shumway, & D. S. Stoffer. : Time series analysis & its applications.
J. D. Cryer, & K.-S. Chan. : Time series analysis with application in R.

STS2PDSE01T/ STS1PDSE01T: Elective Paper (DSE I) [50 marks]

Elective paper 1: Advanced Survey Sampling

The basic model, Sampling Design and sampling schemes, Inclusion probabilities of first two orders, It's relation with effective sample sizes, data and estimators-linear and linear unbiased estimators of population total, Entropy based sampling design, Horvitz Thompson estimator, Generalized difference and generalized regression estimators, issues in non-negative variance estimation and variance of effective sample size, calibration estimation (introduction only). [10]

Inference under super population model, Prediction approach, Model assisted prediction in survey, Asymptotic approach- asymptotic design unbiasedness and consistency, Resampling methods in finite population survey (Concept only).[8]

Survey to deal sensitive data: Randomized 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. [8]

Small Area Estimation - the basic estimation method, Borrowing strength, direct and indirect estimator, ratio and regression estimators for domains. Issues in small domain estimation - synthetic estimators, Model based inference in small area estimation – Fay - Herriot model, Battese-Harter-Fuller model, Empirical Best Linear Unbiased Prediction (EBLUP) (Only elementary idea). [8]

Adaptive sampling for rare and elusive population; Adaptive Cluster Sampling (ACS), Estimation procedures under ACS with SRSWOR and unequal probability sampling. [6]

Introduction to Non-Probability sampling - Convenience Sampling, Judgment (Purposive) Sampling, Quota Sampling, Snowball and Network Sampling, Model-Based Inference in Non-Probability samples. [6]

Data Integration in Survey Sampling - integrating multiple data sources and Integrating probability and Non-probability sampling. [4]

References

C. M. Cassel, E. Sarndal, & J. H. Wretman. : Foundations of inference in survey sampling.
A. Chaudhuri & H. Stenger. : Survey **s**ampling—theory and methods.
A. Chaudhuri. : Essentials of survey sampling.
A. Chaudhuri. : Modern survey sampling.
P. Mukhopadhyay. : Inferential problems in survey sampling.
P. S. Levy, & S. Lemeshow. : Sampling of populations: Methods and applications.
C. E. Sarndal, B. Swensson, & J. Wretman. : Model assisted survey sampling.
S. Thompson & G. Seber. : Adaptive sampling.
W. Fuller. : Sampling statistics.
J. N. K. Rao. : Small area estimation.
P. Mukhopadhyay. : Topics in survey sampling.
A. Chaudhuri & S. Pal. : A Comprehensive Textbook on Sample Surveys.

Elective paper 2: Econometrics & Financial Statistics

Econometric Methods: Single-equation linear model – some variations. Nonparametric methods in econometrics. Simultaneous Equations – identification & estimation. Analysis of Panel Data. Bayesian Econometrics. Demand Analysis. Production Function Analysis. Analysis of some special econometric models. [25]

Statistics in Finance: The value of time, bond pricing with a flat term structure. The term structure of interest rates. The Mean Variance Frontier. The global minimum variance portfolio. Efficient portfolio. The zero beta portfolio. Allowing for a riskless asset. Efficient sets with risk free assets. Pricing of futures contract. Binomial option pricing. Multi-period binomial pricing. Basic Option Pricing. Black-Scholes formula, Extending the Black Scholes formula. Dividends. Risk-free and risky assets. Contracts and options. Continuously compounded interest, present valuation, risk, risk-neutral valuation. Arbitrage: examples, contracts and options under no-arbitrage assumptions. Option Pricing: Cox-Ross-Rubinstein Binomial and Black-Scholes models. Elementary portfolio management, Value-at-risk. [25]

References

J. Johnston. : Econometric Methods
G. G. Judge, et.al. : The theory and practice of econometrics.
W. Greene. : Econometric analysis.
A. Zellner. : An introduction to Bayesian inference in econometrics.
E. Malinvaud. : Statistical methods in econometrics.
H. Wold & L. Jureen. : Demand analysis – a study in econometrics.
P. Sankhayan. : An Intro.to the Economics of Agricultural Production
M. Nerlove. : Estimation and identification of Cobb-Douglas models.
A. Pagan & A. Ullah. : Nonparametric econometrics.
D. Ruppert. : Statistics and finance.
D. Reppert. : Statistics and data Analysis for financial engendering.
E. Lindstrom, H. Madsen, & J. N. Nielsen. : Statistics for finance.
J. Franke, W. K. Hardle, & C. M. Hafner. : Statistics for financial markets.
S. M. Ross. : Introduction to mathematical finance: Options and other topics.
V. S. Bawa, S. J. Brown, & R. W. Klein. : Estimation risk and optimal portfolio choice.
R. Carmona. : Statistical analysis of financial data Using R.

STS2PCOR12T / STS1PCOR02T: Nonparametric Methods & Advanced Design of Experiments [50 marks]

Nonparametric Methods

U-statistics - Definition and Asymptotic properties. [4]

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. [18]

Nonparametric Density Estimation. [3]

Advanced Design of Experiments

Elementary idea of Finite Fields. [5]

Construction of Mutually Orthogonal Latin Squares (MOLS).Construction of BIBD using MOLS and Boses's fundamental method of difference. [6]

Factorial experiment: Confounding and balancing in symmetric factorial experiments-Analysis. [10]
Response surface designs. [4]

References

J. D. Gibbons. : Nonparametric inference.
J. D. Gibbons, & S. Chakraborty. : Nonparametric statistical inference.
T. P. Hettmansperger. : Statistical inference based on ranks.
E. L. Lehmann. : Statistical methods based on ranks.
M. Hollander, D. A. Wolfe, & E. Chicken. : Applied nonparametric statistics.
L. Wasserman. : All in nonparametric statistics.
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.
D. Raghavarao, & L.V.Padgett. : Block design: Analysis, combinatorics and applications.
R. C. Bose. : Mathematical theory of symmetric factorial design (Sankhya – Vol. 8).
D. G. Kabe, and A. K. Gupta. : Experimental designs: Exercises and solutions.

G. Casella. : Statistical design.
T. P. Ryan. : Modern experimental design.
C. F. J. Wu, & M. S. Hamada. : Experiments: planning, analysis and optimization.
D. C. Montogomery. : Design and analysis of experiments.

STS2PCOR13P / STS1PCOR03P: Python Programming I and Advanced Lab I [50 marks]

Python Programming I
Introduction to Python programming: Machine set up: Python and the Anaconda distribution, Required Customisation, os.path, basic I/O, etc.; Variables: Local, Global-their scope and binding etc.; Data Types: Arrays, tuple, set, dictionary, user defined etc.; Loops: Conditionals, Comparisons, Inerrable and Iterators etc.; Functions: Defining and calling, argument Passing, self, recursive etc.; Classes: Methods, Instance variable, initialiser, etc.; Module: export, import, etc.; Style Guide. : docstrings, preceding , Trailing, etc. (25)

Advanced Lab I
Practical exercises based on Time series analysis, Elective paper1/2 (DSE 1), Nonparametric methods and Advanced design of experiments. [25]

References
K. D. Lee: Python programming fundamentals (2nd edition).
J. Zelle.: Python Programming: An Introduction to Computer.
E. Matthes.: Python Crash Course: A Hands-On, Project-Based Introduction to Programming.
M. Lutz. : Python Pocket Reference, 5th Edition.
G. van Rossum & F. L. Drake Jr. : The Python Language Reference Manual.
D. Beazley.: Python Essential Reference.
M. Lutz.: Learning Python.
D. M. Beazley. : Python Distilled.

STS2PCOR14M / STS1PCOR04M: Big Data Analytics [50 marks]

Machine learning: Supervised and unsupervised learning. The 5 v's of a big data problem. The curse of dimensionality: Application of ICA, Prediction accuracy vs. bias.
Measurement of model fit : Cross Validation and information theoretic criteria. Generalization of Linear Regression – Shrinkage methods: Ridge Regression and LASSO.
Partial least squares, Additive models, and Nonlinear models.
Classification Trees and Random Forests.
Classification using a separating hyperplane :The maximal margin classifier and separability, Support Vector Machine, Data piling in high dimension, Case of multiple classes. (50)

References
T. Hastie, R. Tibshirani & J. Friedman:The Elements of Statistical Learning.
B.L. Friedman, et al. : Classification and Regression Trees.
R. Stephen & E. Richard : Independent Component Analysis – Principles and Practice.
R. A. Johnson & D.W. Wichern : Applied Multivariate Statistical Analysis.
G. James et. al. : An Introduction to Statistical Learning with Applications in R.
G. James et. al. : An Introduction to Statistical Learning With Applications in Python.
M. Mohri, A. Rostamizadeh, & A. Talwalkar. : Foundations of Machine Learning.
S. Shalev-Shwartz and S. Ben-David. : Understanding Machine Learning - From Theory to Algorithms.
T. M. Mirtchell. : Machine Learning.
C. M. Bishop.: Pattern Recognition and Machine Learning.
K.P. Murphy. : Probabilistic Machine Learning.

STS2PSEC01M / STS1PSEC01M: Optimization Techniques [50 marks]
Introduction – Basic optimization set-up: objective function, constraints, feasible region; local vs global minima with simple examples from regression and classification. Convex sets and convex functions; typical ML/statistical examples – least squares, logistic loss, hinge loss, L1 and L2 penalties. Empirical risk minimization framework: loss + regularizer; brief illustration via ridge, lasso, and logistic regression. High-dimensional motivation: over-parameterization and the need for regularization and convexity (conceptual discussion only). (10)

Linear Programming and Duality – LP as a foundation for large-scale optimization. Formulation in standard vector–matrix form; examples from resource allocation and basic ML (e.g., SVM in LP form, L1 regression). Geometry of LP: polyhedra, extreme points, basic feasible solutions. Simplex method (conceptual): basic idea and movement along edges (no algorithmic details). Duality in LP: primal–dual pairs, weak and strong duality, complementary slackness. Illustrative examples such as L1 regression and quantile regression as LP. (10)

Convex Programming and KKT – Convex optimization problems: convex objectives and convex feasible sets; examples from statistics and ML such as ridge regression, lasso, and logistic regression with penalties. Lagrangian and dual problem for simple convex programs (conceptual treatment). Karush–Kuhn–Tucker (KKT) conditions: stationarity, primal feasibility, dual feasibility, complementary slackness (without proof). Basic idea of constraint qualifications at an intuitive level. Applications: KKT for ridge regression and simple constrained least squares; interpretation of sparsity in lasso (subgradient idea in low dimension). (14)

Algorithms for Large-Scale Convex Optimization – Gradient-based methods: steepest descent, role of step size, basic convergence intuition in convex problems. Newton and quasi-Newton methods (only when and why they are used, not full derivations). First-order methods for large-scale ML: Stochastic Gradient Descent (SGD) – single-sample and mini-batch updates, choice of learning rate; brief idea of coordinate descent and proximal methods with reference to lasso/elastic net. Emphasis on modeling and understanding algorithm behaviour rather than detailed convergence proofs. (10)

Integer and Stochastic Programming – Integer Programming: basic 0–1 and general integer formulations; idea of LP relaxation and branch-and-bound (conceptual). Simple applications: best subset selection via binary variables, and design/selection problems under integer constraints. Stochastic Programming: motivation from optimization under uncertainty; very simple two-stage or chance-constrained formulations with examples (e.g., reliability or risk-limited portfolios); link to empirical risk minimization and Monte Carlo at an intuitive level. (6)

Reference Books:
D.G. Luenberger, and Y. Ye – Linear and Nonlinear Programming.
S. Boyd, S., and L. Vandenberghe – Convex Optimization.
J. Nocedal, J., and S. J. Wright – Numerical Optimization.
Hastie, T., R. Tibshirani, and J. Friedman – The Elements of Statistical Learning.
G. James et. al. : An Introduction to Statistical Learning with Applications in R (ISLR).
H. Wickham, and G. Grolemund. : R for Data Science.
B. Lantz. : Machine Learning with R.

Semester IV (2-Year M.Sc. in Statistics) / Semester II (1-Year M.Sc. in Statistics)

STS2PCOR15T / STS1PCOR05T: Decision Theory & Bayesian Inference [50 marks]

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

Bayesian Methods: Overview and comparison of different paradigms, Relative advantages and disadvantages. Priors & Posteriors : Subjective priors, Conjugate and other Non-subjective priors. Bayesian

Inference : Estimation, testing, interval estimation and prediction for some common models and common priors. Hierarchical and Empirical Bayes Methods. Bayesian Computation. [15]

Bayesian linear Model and Regression. Hierarchical and Empirical Bayes estimation. parametric empirical Bayes estimator and its computation. Bayesian computation and simulation: Markov Chain Monte Carlo (MCMC), Gibbs Sampling, Metropolis Hastings (MH) algorithm. Testing and Model selection. [25]

References

T. S. Ferguson: Mathematical statistics
E. L. Lehmann & G. Casella: Theory of point estimation
J. O. Berger: Statistical decision theory and Bayesian analysis
J. Pratt & H. Raiffa: Introduction to statistical decision theory
F. Liese & K.-J. Miescke: Statistical decision theory
P. D. Hoff: A first course in Bayesian statistical methods
G. E. P. Box & G. C. Tiao: Bayesian inference in statistical analysis
J.-M. Marin & C. P. Robert: Bayesian Essentials with R
J. Albert: Bayesian Computation with R
J. K. Ghosh, M. Delampady & T. Samanta: An introduction to Bayesian analysis: Theory and methods
B. P. Carlin & T. A. Louis: Bayesian methods for data analysis
C. P. Robert: The Bayesian choice
J.-M. Marin & C. P. Robert: Bayesian Core: A practical approach to computational Bayesian statistics
A. Gelman, J. B. Carlin, H. S. Stern, D. B. Dunson, A. Vehtari & D. B. Rubin: Bayesian Data Analysis.

STS2PCOR16T / STS1PCOR06T: Data Analytic Methods & Categorical Data Analysis [50 marks]

Data Analytic Methods

Missing data methods: Inference for data with missing values. Different types of missing data mechanism. MLE using E-M algorithms. MCEM algorithm, Various imputation techniques & MICE. [10]

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 for the methods in i.i.d. set-up. Bootstrap confidence intervals and its computational aspects. [10]

Monte Carlo methods: Introduction to Importance sampling and Markov Chain Monte Carlo (MCMC).[5]

Categorical Data Analysis

Categorical Response Data: Nominal/ Ordinal Distinction, Probability Distributions for Categorical Data-Binomial & Multinomial Distributions. [5]

Inference for a proportion: Wald, Score, and Likelihood-Ratio Inference for Binomial Parameter. 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. [13]

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. [7]

References

R. J. A Little, & D. B. Rubin. : Statistical analysis with missing data.
C. K. Enders. : Applied missing data analysis.
T. Raghunathan. : Missing data analysis in practice.
B. Efron & R. J. Tibshirani. : An introduction to the bootstrap.
A. C. Davison, & D.V. Hinkley. : Bootstrap methods and their applications.

J. Shao, & D. Tu. : The jackknife and bootstrap.
M. R. Chernick, & R. A. LaBudde. : An introduction to bootstrap methods with application to R.
C. P. Robert & G. Casella: Monte Carlo Statistical Methods.
C. P. Robert & G. Casella: Introducing Monte Carlo Methods with R.

STS2PDSE02T / STS1PDSE02T: Elective 2 (DSE 2) [50 marks]

Elective Paper 1: Biostatistics
Survival Analysis: Concepts of lifetime. Various schemes of censoring and associated likelihood functions. Estimation of survival function: Parametric procedure: Point estimation, Scores and likelihood ratio tests for selected parametric models and confidence intervals. Distribution free procedures: Actuarial estimator, Kaplan-Meier and Nelson – Aalen estimators. Regression models: Estimation in parametric and Semi-parametric models-Cox's proportional hazard model, Time dependent covariates, Rank test. Competing risk analysis and multivariate models. [25]

Clinical Trials: Ethical issues in Clinical Trials and its different phases, Sample size determination, Brief introduction to Simple randomized design, stratified randomized crossover design and Sequential designs. [8]

ROC Curve Analysis: ROC curve for validity Diagnostic test-Examples from medical field, Population ROC curves-it's properties, Slope of ROC curve and optimality results, Area under ROC (AUC) measure, Bi-normal model and Binary regression model-estimation of ROC curve. [9]

Statistics in Epidemiology: Definition of Epidemiology. Measures of disease frequency-incidence, prevalence and relative risk, Epidemiological study designs – Cohort study and Case control study designs and analysis. [8]

References
R. G. Miller. : Survival analysis.
D. J. Kleinbaum & M. Klein. : Survival analysis: A self-learning text.
D. W. Hosmer, S. Lemeshow, & S. May. : Applied survival analysis: Regression modelling of time to event data.
J. P. Klein, & M. L. Moeschberger. : Survival analysis: Techniques for censored and truncated data.
J. D. Kalbfleisch, & R. L. Prentiice. : The statistical analysis of failure time data.
D. F. Moore. : Applied survival analysis using R.
S. Piantadosi. : Clinical Trials - A Methodologic Perspective.
B.S. Everitt & A. Pickles. : Statistical Aspects of Design & Analysis of Clinical Trials.
S.J. Pocock. : Clinical Trials.
J. Whitehead. : The Design and Analysis of Sequential Clinical Trials.
W. F. Rosenberger & J.M. Lachin. : Randomization in Clinical Trials- Theory and Practice.
W. J. Krzanowski & D. J. Hand.: ROC Curves for Continuous Data.
M. S. Pepe.: The statistical evaluation of medical tests for classification and prediction.
X.-H. Zhou, N. A. Obuchowski, & D. K. McClish. : Statistical Methods in Diagnostic Medicine.
K. J. Rothman & S. Geenland. : Modern Epidemiology.
S. Selvin. : Statistical Analysis of Epidemiologic Data.
D. McNeil. : Epidemiological Research Methods.
S. C. Newman.: Biostatistical Methods in Epidemiology.
J.F. Jekel, J.G. Elmore, & D.L. Katz. : Epidemiology, Biostatistics and Preventive Medicine.
Mark Woodward.: Epidemiology: Study Design and Data Analysis.

Elective Paper 3: Industrial Statistics
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]

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
H. A. Taha. : Operational research.
F. S. Hillier, & G. J. Leiberman. : Introduction to operations research.
K. 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.
M. Sasieni, A. Yaspan, & L. Friedman. : Operations research.
R. L. Ackoff, & M. W. Sasieni : Fundamentals of operation research.
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.

STS2PCOR17T / STS1PCOR07T: Applied Multivariate Analysis [50 marks]

Multivariate linear regression model: estimation of parameters, tests of linear hypotheses, different test criteria, Multivariate Analysis of variance of one and two way classified data. Multivariate Analysis of Covariance. [15]

Hierarchical and non-hierarchical clustering methods. [8]

Classification and discrimination procedures for discrimination between two known populations – Bayes, Minimax and Likelihood Ratio procedures. Discrimination between two multivariate normal populations. Sample discriminant function. Likelihood ratio rule. Tests associated with discriminant function, Probabilities of misclassification and their estimation. Classification of several populations. Fisher's method for discriminating among several populations. [10]

Population and sample principal components and their uses and related large sample inference. [5]

The orthogonal factor model, Estimation of factor loading, Factor rotation, Estimation of Factor scores, Interpretation of Factor Analysis. [7]

Canonical variables and canonical correlations (population & sample) and their interpretations. Large sample inferences. [5]

References

R. A. Johnson, & D. W. Wichern. : Applied multivariate statistical analysis.
N. H. Timm. : Applied multivariate analysis.
A. V. Rencher, & W. F. Christensen. : Methods of multivariate analysis.
W. K. Hardle, & L. Simar. : Applied multivariate statistical analysis.
T. W. Anderson.: An introduction to multivariate statistical analysis.
G. A. F. Seber.: Multivariate observations.
R. J. Muirhead. : Aspects of multivariate statistical theory.
M. Bilodeau, & D. Brenner. : Theory of multivariate statistics.
P. Mukhopadhyay. : Multivariate statistical analysis.
A.V. Rencher. : Multivariate statistical inference and applications.
B. Everitt & T. Hothorn. : An introduction applied multivariate analysis with R.

STS2PCOR18P / STS1PCOR08P: Python Programming II & Advanced Lab II [50 marks] :

Python Programming II

Statistics using Python: Data representation, file handling, tables & plots; Linear regression, multiple factors, and analysis of variance; Probability distributions and random sampling.
Some important packages: Managing data with NumPy and pandas; Graphs with matplotlib and seaborn; Statistical analysis with statsmodels. [25]

Advanced Lab II

Practical exercises based on Decision theory & Bayesian inference, Data analytic methods & Categorical data analysis, Elective paper 1/2 (DSE 2) and Applied multivariate analysis. [25]

References

T. Haslwanter: An introduction to statistics with Python.
J. Unpingco. Python for probability, statistics, and machine learning (2nd edition).
J. Rogel-Salazar. Data science and analytics with Python.

STS2PCOR19M / STS1PCOR09M: Project Work & Seminar Presentation [50 marks]

This paper consists of a Project Report and a Seminar Presentation based on the project work throughout the Semester.