# UNIVERSITY OF CALCUTTA

**Revised Syllabus & Admission Rules for Two-year M.Sc. Course**
**&**
**Regulations for the M.Sc. Examinations**
in
## STATISTICS

## 2017

A student will be eligible for admission to the course if he/she is an Honours graduate in Statistics from Calcutta University or has passed the B.Sc. (Honours) in Statistics /B.Stat examination securing 60% marks in the aggregate from any other University/Institution.

In general the regulations for the two year (four semester) M.Sc. degree course in Statistics applicable from the academic year 2017-18 will be same as the comprehensive and uniform regulations of Calcutta University (Notification CSR/ 55/ 09).

Some particular points in the regulations for the Examinations in each of the semesters are as follows:

1. Each semester will have a number of courses as detailed below. Each course will comprise of either a Theoretical component or a Practical component or both.
2. The end-semester examinations for the theoretical papers will be held after the completion of the classes of that semester. Twenty five percent of the marks in each theoretical paper will be awarded based on internal assessment, which will include a mid–semester test and/or any other form of assessment as decided by the concerned teacher. The Practical papers will be marked based on continuous assessment as well as a final Viva-Voce examination.
3. Twenty five percent credit points are allotted to each semester. One theory credit point is equivalent to one hour of class per week while one practical credit point is equivalent to one and a half hours of class per week.

4. The examinations for theoretical papers (excluding internal assessment marks) with 41-50 marks and 51-75 marks will be of 2 hours and 3 hours duration, respectively.

5. Each credit point is equivalent to 20 marks in the examinations.

6. Students need to appear at the examination of each and every paper in each course. In order to be declared pass, the student must obtain at least 40% marks in each course. In case of courses containing both theoretical and practical parts, students must secure at least 35% of marks in theoretical papers and at least 35% of marks in practical papers separately and at least 40% marks in the aggregate to be deemed passed in that course.

7. Students failing to obtain pass marks in 1 or 2 courses can sit for a supplementary examination in the concerned course to be held usually within six months of the original examination. Students can however continue their studies in the higher semesters. Students failing in a supplementary examination can have a final chance of clearing the paper during the regular examination of the paper in the following session. However, students unable to clear the supplementary examination in any course in the 3rd or 4th semesters may be allowed to take a second supplementary examination within six months of the end of the 4th semester.

8. Students failing to obtain pass marks in more than 2 courses in a semester will be deemed to have failed in the semester as a whole and will need to clear that semester in subsequent sessions before moving on to the next semester.

9. Students will be required to select 2 elective papers in the 3rd semester and 3 elective papers in the 4th semester. These are detailed in the syllabus of the respective semester. Some of the elective papers may be pre-requisites/ requisites for other elective papers (as mentioned in the syllabus).

10. Students will be required to do a minor project in the 1st semester. They will be required to submit a written report and/or make a formal presentation at the end of the semester.

11. Students will need to start their major project work in the 3rd semester and continue the same in the 4th semester. They will be required to submit a written report and also make formal presentation(s) at the end of the 4th semester.

# <u>Syllabus for M.Sc. Examination in Statistics</u>

*(Credit points and marks on two right-hand columns are shown as Theoretical credits (marks) + Practical credits (marks))*

**Semester I : Total credits = 25   (Total Marks = 500)**

| Course No. | SUBJECT | CREDIT POINTS | MARKS |
|---|---|---|---|
| STAT 101 : | Analysis I | 4 + 0 | 80 + 0 |
| STAT 102 : | Probability I | 4 + 0 | 80 + 0 |
| STAT 103 : | Statistical Inference I | 3 + 1 | 60 + 20 |
| STAT 104 : | Linear Algebra & Linear Models | 4 + 1 | 80 + 20 |
| STAT 105 : | C Programming | 0 + 3 | 0 + 60 |
| STAT 106 : | R Programming | 0 + 3 | 0 + 60 |
| STAT 107 : | Project/Seminar | 2 | 40 |

**Semester II : Total credits = 25  (Total Marks = 500)**

| Course No. | SUBJECT | CREDIT POINTS | MARKS |
|---|---|---|---|
| STAT 201 : | Probability II | 3 + 0 | 60 + 0 |
| STAT 202 : | Multivariate Analysis | 4 + 1 | 80 + 20 |
| STAT 203 : | Statistical Inference II | 4 + 1 | 80 + 20 |
| STAT 204 : | Regression Analysis I | 3 + 1 | 60 + 20 |
| STAT 205 : | Design of Experiments | 3 + 1 | 60 + 20 |
| STAT 206 : | Sample Surveys | 3 + 1 | 60 + 20 |

**Semester III : Total credits = 25 (Total Marks = 500)**

In this semester, students will be required to select one elective paper from each of two groups as listed below. Each of the groups contains 5 papers. However, all of these may not be offered in a particular year and it will be at the discretion of the Department to decide which papers to offer in the particular year. *Some of the elective papers are pre-requisites of certain special modules (as discussed in Semester IV) to be chosen in the 4th semester and hence are to be viewed accordingly.*

| Course No. | SUBJECT | CREDIT POINTS | MARKS |
|---|---|---|---|
| STAT 301 : | Statistical Inference III | 3 + 1 | 60 + 20 |
| STAT 302 : | Regression Analysis II | 3 + 1 | 60 + 20 |
| STAT 303 : | Applied Multivariate Analysis | 3 + 1 | 60 + 20 |
| STAT 304 : | Time Series Analysis & Development Statistics | 4 + 1 | 80 + 20 |
| STAT 305-309 : | Elective 1 | 3 + 1 or 4 + 0 | 60 + 20 or 80 + 0 |
| STAT 310-314 : | Elective 2 | 3 + 1 or 4 + 0 | 60 + 20 or 80 + 0 |

**Choice of Elective papers :**

Elective 1 :   *Any one from the following*

　　　STAT 305 :   Analysis II     (*pre-requisite* for STAT 403)

　　　STAT 306 :   Applied Bayesian Methods

　　　STAT 307 :   Regression Designs

　　　STAT 308 :   Operations Research       (*pre-requisite* for STAT 416)

　　　STAT 309 :   Demography

Elective 2 :   *Any one from the following*

　　　STAT 310 :   Probability III

　　　STAT 311 :   Advanced Sample Survey

　　　STAT 312 :   Survival Analysis     (*pre-requisite* for STAT 405 & STAT 410)

　　　STAT 313 :   Actuarial Statistics

　　　STAT 314 :   Optimization Techniques

**Semester IV : Total credits = 25 (Total Marks = 500)**

In this semester, students will be required to select one elective paper from each of three groups as listed below. Each of the groups contains 5 papers. However, all of these may not be offered in a particular year and it will be at the discretion of the Department to decide which papers to offer in the particular year.

| Course No. | SUBJECT | CREDIT POINTS | MARKS |
|---|---|---|---|
| STAT 401 : | Stochastic Processes | 3 + 0 | 60 + 0 |
| STAT 402 : | Adv. Data Analytic Techniques | 3 + 2 | 60 + 40 |
| STAT 403-408 : | Elective 3 | 3 + 1 or 4 + 0 | 60 + 20 or 80 + 0 |
| STAT 409-414 : | Elective 4 | 3 + 1 or 4 + 0 | 60 + 20 or 80 + 0 |
| STAT 415-420 : | Elective 5 | 3 + 1 or 4 + 0 | 60 + 20 or 80 + 0 |
| STAT418 : | Project Work | 0 + 5 | 0 + 100 |

**Choice of Elective Papers :**

Elective 3 :   *Any one from the following*

      STAT 403 :   Probability IV          (*requisite* STAT 305)

      STAT 404 :   Advanced Parametric Inference

      STAT 405 :   Clinical Trials and Bioassay (*requisite* STAT 310 & STAT 410)

      STAT 406 :   Statistical Quality Management

      STAT 407 :   Statistical Analysis of Big Data

Elective 4 :   *Any one from the following*

      STAT 408 :   Applied Stochastic Models

      STAT 409 :   Nonparametric Methods

      STAT 410 :   Epidemiology          (*requisite* STAT 312 & STAT 405)

      STAT 411 :   Reliability Theory

      STAT 412 :   Directional and Spatial Statistics

Elective 5 :   *Any one from the following*

      STAT 413 :   Sequential and Semiparametric Methods

      STAT 414 :   Econometrics

      STAT 415 :   Statistical Genetics

      STAT 416 :   Advanced Operations Research   (*requisite* STAT 308)

      STAT 417 :   Astrophysics and related data sources

# Detailed Syllabus

## Semester I

### STAT 101 : Analysis I  (4+0)

Sequences, subsequences, convergence, divergence, bounded sequences, limits superior and inferior, monotone sequences, Cauchy sequences, completeness.                                    (9)

Bounded and unbounded subsets of the line, intervals, closed and open sets, characterizations, limit points, closures, interiors. Denseness. Compact sets. Heine-Borel, Bolzano-Weirstrass Theorems (statements).                                    (8)

Functions : limits, continuity, uniform continuity, intermediate value theorem, differentiability; mean value theorem, Taylor's theorem (statement), extrema.                                    (8)

Series of real numbers.                                    (3)

Sequences and series of functions, uniform convergence, power series, term-by-term differentiation and integration.                                    (6)

Multivariate calculus:  partial, directional and total derivatives, mean value theorem.       (6)


***References :***

| | | |
|---|---|---|
| T.M.Apostol | : | Mathematical Analysis |
| W.Rudin | : | Principles of Mathematical Analysis |
| D. R. Sherbert & R.G. Bartle | : | Introduction to Real Analysis, 4ed |
| S. R. Ghorpade &  B.V. Limaye | : | A Course in Calculus and Real Analysis |
| S. R. Ghorpade & B.V. Limaye | : | A Course in Multivariable Calculus and Analysis |
| R.R.Goldberg | : | Methods of Real Analysis |


### STAT 102 : Probability I (4+0)

Fields, sigma-fields and generators, semifields, Borel sigma-field on R. Monotone classes, monotone class theorem, pi-lambda theorem.                                    (8)

Measures, finite, sigma-finite measures. Probability measures, properties. Independence of events, Borel-Cantelli lemmas.                                    (5)

Measurable functions and properties, Generated sigma-fields. Induced measures. Compositions. Examples. (4)

Extensions of measures, Caratheodory's theorem (statement). Lebesgue measure on R: construction, properties. (3)

Random variables and vectors, probability distributions, distribution functions. (2)

Convergence in measure, almost everywhere and their connection. (1)

Integration, simple, nonnegative, general measurable functions, integrability. Expectations, moments. Monnotone Convergence Theorem, Dominated Convergence Theorem, Fatou's lemma. Connection with Riemann Integration Change of variables. (14)

Absolute continuity and singularity of measures. Radon-Nikodym Theorem (Statement). Discrete and absolutely continuous distributions. Lebesgue's differentiation theorem (statement), probability densities. (3)

### *References :*

| | | |
|---|---|---|
| S. Resnick | : | A Probability Path |
| M. Capinski & T. Zastawniak | : | Probability Through Problems |
| P. Billingsley | : | Probability and Measure |
| R. Ash & C. Doleans-Dade | : | Probability and Measure Theory |
| A. K. Basu | : | Measure Theory and Probability |

## STAT 103 : Statistical Inference I (3+1)

### Point Estimation (10)

Sufficiency and completeness, Exponential and Extended Exponential families. (5)

Rao-Blackwell and Lehmann-Scheffe Theorems, Minimum Variance Unbiased Estimators. (5)

### Testing of Hypotheses I (12)

Review of notions of nonrandomized and randomized tests, level, size, p-value, power function, Fundamental Neyman-Pearson lemma, UMP Tests. (7)

Monotone Likelihood Ratio. (3)

Confidence sets, relation with hypothesis testing, UMA confidence intervals. (2)

**Sequential Analysis** (**8**)

Stopping variables, Sequential Tests, Wald's equation for ASN, SPRT and its properties – fundamental identity, OC and ASN, Optimality of SPRT (under usual approximation).     (8)

***References :***

| E.L.Lehman | : | 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 |
| B.K.Ghosh | : | Sequential Tests of Statistical Hypotheses |
| A. Wald | : | Sequential Analysis |
| N. Mukhopadhyay& B. M. de Silva: | | Sequential methods and their applications |

## STAT 104 : Linear Algebra and Linear Models (4+1)

**Linear Algebra (15)**

Vector spaces and subspaces, Rank and basis, Orthogonality – projections and least squares approximation, Eigen values and eigen vectors and related inequalities, Linear transformation.     (15)

**Linear Models (25)**

Gauss Markov Model: Estimable function, error function, BLUE, Gauss Markov theorem. Correlated set-up, least squares estimate with restriction on parameters.     (8)

Linear Set, General linear hypothesis – related sampling distribution, Multiple comparison techniques due to Scheffe and Tukey.     (6)

Analysis of variance: Balanced classification, Fixed Effects Model, Random Effects Model and Mixed Effects Model; Inference on Variance components.     (7)

Regression analysis     (1)

Analysis of covariance.     (3)

***References :***

| G. Hadley | : | Linear Algebra |
|---|---|---|

| C.R. Rao | : | Linear Statistical Inference and its Applications |
| G. Strang | : | Introduction to Linear Algebra |
| D. C. Lay | : | Linear Algebra and its Applications |
| R. B. Bapat | : | Linear Algebra and Linear Models |
| A. R. Rao & P.Bhimasankaram | : | Linear Algebra | : |
| H.Scheffe | : | The Analysis of Variance |
| S.R.Searle | : | Linear Models |
| G.A.F.Seber | : | Linear Regression Analysis |
| N.C. Giri | : | Analysis of Variance |

## STAT 105 : C Programming (0+3)

Overview of C language: Simple Syntax, loops, pointers, arrays, functions, files.

Algorithms and corresponding C-programs for

1. Sorting and Searching

2. Generation of Random Numbers and tests for randomness

3. Generation of samples from different theoretical distributions

4. Monte Carlo Integration

5. Acceptance-Rejection sampling

6. Importance Sampling

*7.* Missing data analysis

*References :*

| B.W.Kernighan & D.M.Ritchie | : | The C Programming Language |
| D.E.Knuth | : | The Art of Computer Programming (Vol. 1 &2) |
| W.H.Press et.al | : | Numerical Recipes in C |
| N.Wirth | : | Algorithm and Data Structures |

## STAT 106 : R Programming (0+3)

Data types in R.

R Graphics.

Basic statistics using R.

Vector matrix operations :Simple matrix operations; Linear equations and eigenvalues, Matrix decomposition – LU, QR and SVD; Matrix inverse and G inverse; Finding a basis, orthonormalisation, 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.

Random number generation & Simulations.

Programming in R.

Useful libraries: MASS, optim, maxLik, dplyr, ggplot2.


### References :

| | | |
|---|---|---|
| P. Dalgaard | : | Introductory Statistics with R, Springer, 2nd ed, 2008. |
| J. Maindonald & J. Braun | : | Data Analysis and Graphics Using R , Cambridge University Press, Cambridge, 2nd edition, 2007. |
| J.J. Faraway | : | Linear Models with R ,Chapman& Hall/CRC Texts in Statistical Science. |


# Semester II


## STAT 201 : Probability II (3+0)

Product sigma-fields, Borel sigma-field on Euclidean spaces. Product measures. Fubini's theorem. Lebesgue measure on $R^k$. (4)

Convergence in distribution. Examples. Portmanteau theorem (statement and applications). Scheffe's theorem, Slutsky's theorem. (5)

Holder's, Minkowski's and Jensen's inequalities. $L_p$ spaces, Lp-convergence of random variables, connections with other modes of convergence. (4)

Independence of random variables, their partial sums. Kolmogorov's 0-1 law. Kolmogorov's inequality. (2)

Integration of complex-valued functions, characteristic functions. Convolutions. Inversion and Continuity theorems. (5)

Weak and strong laws of large numbers. (6)

Central Limit Theorems. (4)

### *References :*

| S. Resnick | : | A Probability Path |
| P. Billingsley | : | Probability and Measure |
| R.Ash & C. Doleans-Dade | : | Probability and Measure Theory |
| K. B. Athreya & S. N. Lahiri | : | Measure Theory and Probability Theory |
| A. K. Basu | : | Measure Theory and Probability |

## STAT 202 : Multivariate Analysis (4+1)

Non-central $X^2$ , t & F distributions – definitions and selected properties. (3)

Distribution of quadratic forms – Cochran's theorem. (4)

Sampling from Multivariate normal distribution – independence of sample mean vector and variance-covariance matrix. Wishart distribution. (6)

Distributions of partial and multiple correlation coefficients and regression coefficients. (4)

Hotelling $T^2$ and Mahalanobis $D^2$ applications in testing and confidence set construction. (3)

Multivariate linear model: estimation of parameters, tests of linear hypotheses, Multivariate Analysis of variance of one and two way classified data (only LR test). (10)

Principal Component Analysis: Population and sample principal components and their uses. Biplot,, Large sample inferences. (4)

Factor Analysis: The orthogonal factor model, Estimation of factor loading, Factor rotation, Estimation of Factor scores, Interpretation of Factor Analysis. (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 |

## STAT 203 : Statistical Inference II (4+1)

**Testing of Hypotheses II & Confidence Set Estimation (14)**

UMPU Tests: One parameter exponential family.                                    (2**)**

Generalized Neyman-Pearson Lemma.                                               (1)

Locally best tests.                                                            (2)

Similar tests, Neyman structure, UMPU tests for composite hypotheses.           (6)

UMAU  confidence intervals.                                                    (3)

**Asymptotic Inference (12)**

Consistency and Asymptotic Efficiency of Estimators, Maximum Likelihood estimators and
their Large sample properties.                                                 (7)

Asymptotic distributions and properties of Likelihood ratio tests, Rao's score test and
Wald's tests in the simple hypothesis case.                                    (5)

**Bayesian Analysis** (**14**)

Elements of decision theory: Preliminary ideas of decision rules, loss and risk.    (2)

Overview and comparison of two paradigms – Classical statistical analysis and Bayesian
analysis.Relative advantages and disadvantages, Motivation for choice of different priors.

(5)

Bayesian Inference – estimation, testing, interval estimation and prediction for some
common models and common priors, Hierarchical Bayes, Brief discussions on Bayesian
computational techniques and their applications.                              (7)


***References:***

R.J. Serfling                    :        Approximation Theorems of Mathematical Statistics

E.L. Lehmann                   :        Large Sample Theory

C.R. Rao                       :        Statistical Inference and its Applications

J.O. Berger                    :        Statistical Decision Theory and Bayesian Analysis

J.K. Ghosh, M. Delampady & T. Samanta        :        Bayesian Inference

P. Lee                         :        Bayesian Statistics – An Introduction

## STAT 204 : Regression Analysis I (3+1)

Building a regression model: Transformations – Box-Cox and Box-Tidwell models, Stepwise regression, Model selection (adjusted $R^2$, cross validation and Cp criteria, AIC, PRESS) .(7)

Multicollinearity – detection and remedial measures. (4)

Dummy variables, piecewise regression, splines and scatter plot smoothing. (4)

Detection of outliers and influential observations: residuals and leverages, DFBETA, DFFIT, Cook's Distance and COVRATIO. (4)

Checking for normality: Q-Q plots, Normal Probability plot, Shapiro-Wilks test. (3)

Departures from the Gauss-Markov set-up : Heteroscedasticity and Autocorrelation – detection and remedies. (8)

*References :*

| | | |
|---|---|---|
| N.R. Draper & H. Smith | : | Applied Regression Analysis |
| D.W. Belsley, E. Kuh & R.E. Welsch | : | Regression Diagnostics – identifying Influential data & sources of collinearity |
| J. Rousseeuw & A.M. Leroy | : | Robust Regression & Outlier Detection |
| R.D. Cook & S. Weisberg | : | Residual and its Influence in Regression |
| J. Johnston | : | Econometric Methods (3rd ed.) |
| G.G. Judge, W.E. Griffith, R.C. Hill, W. Lutkepohl & T.C. Lee : | | The Theory and Practiceof Econometrics (2nd ed.) |
| T.P. Ryan | : | Modern Regression Methods (2nd ed.) |
| J.O. Rawlings, S.G. Pantula & D.A. Dickey : | | Applied Regression Analysis: A Research Tool |
| S. Chatterjee & A.S. Hadi | : | Regression Analysis by Example |

## STAT 205 : Design of Experiments (3+1)

Block Designs: Connectedness, Orthogonality, Balance and Efficiency; Resolvable designs. Properties of BIB designs, Designs derived from BIB designs. (7)

Intrablock analysis of BIB, Recovery of inter-block information in BIB designs; Row column and Youden Square designs, Missing plot technique. Elementary ideas of Lattice and PBIB designs. (7)

Construction of mutually orthogonal Latin Squares (MOLS); Construction of BIBD through MOLS and other ways. (5)

Factorial designs: Analysis, Confounding and balancing in Symmetric Factorials. (8)

Response Surface Designs. (3)


### *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 |
| 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 (2nd edition) |
| D.C. Montogomery | : | Design and Analysis of Experiments |


## STAT 206 : Sample Surveys  (3+1)

Probability sampling from a finite population – Notions of sampling design, sampling scheme, inclusion probabilites, Horvitz-Thompson estimator of a population total. (4)

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-Hurwitz estimator in

unequal probability sampling with replacement, Des Raj and Murthy's estimator (for sample size two) in unequal probability sampling without replacement. (10)

Stratified sampling – Allocation problem and construction of strata. (3)

Ratio, Product, Difference and Regression estimators. Unbiased Ratio estimators – Probability proportional to aggregate size sampling, Hartley – Ross estimator insimple random sampling. (5)

Two-stage sampling with unequal number of second stage units and simple random sampling without replacement / unequal probability sampling with replacement at first stage, Ratio estimation in two-stage sampling. (5)

Doube sampling for stratification. Sampling on successive occasions. (3)

### References :

| | | |
|---|---|---|
| W.G. Cochran | : | Sampling Techniques, 3rded. |
| Des Raj & Chandak | : | Sampling Theory |
| A.S. Hedayat & B.K. Sinha | : | Design and inference in finite population sampling |
| P. Mukhopadhyay | : | Theory & Methods of Survey Sampling |
| M.N. Murthy | : | Sampling Theory and Methods. |

# Semester III

## STAT 301 : Statistical Inference III (3+1)

**Decision Theory** (**15**)

Decision Problem and two-person game, Nonrandomized and randomized rules, Risk function, Admissibility of decision rules, Complete, essentially complete, minimal complete and minimal essentially complete classes. Essential completeness and completeness of class of rules based on sufficient statistic and the class of nonrandomized rules for convex loss. (6)

Bayes rules, Extended Bayes, Generalized Bayes and Limit of Bayes rules, Admissibility of Bayes rule. (5)

Minimax rules, Method for finding minimax rules. (4)

**Nonparametric Methods** (**15**)

Elementary concepts of U-statistics and Linear Rank Statistics, Single sample location, location cum symmetry and goodness-of-fit problem. (5)

Two-sample location, scale and homogeneity problems, Multi-sample location problem, Bivariate association problem. (6)

Related nonparametric interval estimation; Concept of asymptotic relative efficiency. (4)

### *References :*

| | | |
|---|---|---|
| C.R. Rao | : | Linear Statistical Inference and its Applications |
| E.L. Lehmann | : | Theory of Point Estimation |
| T.S. Ferguson | : | Mathematical Statistics |
| D.A.S. Fraser | : | Nonparametric methods in Statistics |
| J.D. Gibbons | : | Nonparametric Inference |
| T.P. Hettmansperger | : | Statistical Inference based on ranks |
| J.O. Berger | : | Statistical Decision Theory and Bayesian Analysis |

## STAT 302 : Regression Analysis II (3+1)

Measures of association for classified nominal and ordinal categorical data**.** (8)

Generalized Linear Models**:** Introduction, Components of a GLM, Maximum Likelihood estimation, Deviance. (6)

Binary data and Count data: ungrouped and grouped.Models with constant coefficient of variation.Polytomous data. (8)

Overdispersion and fitting by quasi-likelihood. (3)

Extensions of GLMs: Zero inflated Poisson models,.Joint modeling of mean and variance, Concept of Generalized Additive Models (GAM). (8)

### *References :*

| | | |
|---|---|---|
| A. Agresti | : | Analysis of Ordinal Categorical Data |
| A. Agresti | : | Categorical Data Analysis |
| P.McCullagh&A.J.Nelder | : | Generalized Linear Models |
| C.E.McCullough&S.R.Searle | : | Generalized, Linear and Mixed Models, 2nded. |
| T.Hastie&R.Tibshirani | : | Generalized Additive Models |

## STAT 303 : Applied Multivariate Analysis (3+1)

Clustering of Observations: Hierarchical clustering for continuous and categorical data-different choices of proximity measures, Agglomerative and Divisive algorithms, K-means clustering optimum  choice of the number of clusters, Silhouette Index. (8)

Clustering of Variables. (2)

Classification and discrimination procedures: 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. (9)

Canonical Correlation: Population and sample canonical variables and canonical correlations and their interpretations. (3)

Multidimensional Scaling. (2)

Correspondence Analysis. (2)

Content Analysis: Steps in Content Analysis, Reliability of coded data, Interpretation of the result. (4)

### *References :*

T.W. Anderson : An Introduction to Multivariate Statistical Analysis, (2nded.)

N.C. Giri : Multivariate Statistical Inference

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

S.C. Sharma : Applied Multivariate Techniques

## STAT 304 : Time Series Analysis and Development Statistics (4+1)

**Time Series Analysis (26)**

Introduction : Classical Models, Smoothing Techniques – exponential and Holt-Winters methods. (3)

Evolutionary and Stationary time series. Autocorrelation and partial autocorrelation functions. Box-Jenkins Model. Tests for Unit Roots. (8)

Volatility : ARCH, GARCH models – their variants. (6)

Multivariate Time Series Models : VAR and VARMA models. (3)

Forecasting. (2)

Analysis in the Frequency Domain : The Sprectum and Periodogram Analysis. (4)

**Development Statistics (14)**

Concept of economic development – role of statistics. National and international statistical systems. National accounts – estimation of national income. (4)

Measurement of Poverty, Inequality and Unemployment. (8)

Development indices. (2)

*References :*

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

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

P.J. Brockwell & R.A. Davis :      Introduction to Time Series Analysis and Forecasting

A.Pankratz                           :        Forecasting with Univariate Box-Jenkins Model

G. Janacek and L. Swift    :      Time Series  –Forecasting, Simulation, Applications

CSO (2007)                       :        National Accounts Statistics – Sources and Methods

A.Sen                               :        Poverty and Inequality

Y.P.Chaubey                     :        Poverty Measurements : issues, approaches and indices

UNO                               :        Yearly Human Development Reports

# Elective Papers
## Elective - 1

## STAT 305 : Analysis II (4+0)

Examples of infinite-dimensional vector spaces. Norms and Inner products on vector spaces, orhtogonality. Seminorms and quotient spaces. (4)

Metric spaces : open, closed, closures, interiors, dense sets, sequences and limits, subsequences, completeness, compactness, separability and consequences. Functions and continuity, uniform continuity, connectedness. (15)

Hilbert spaces, orthonormal basis, applications to Statistics. Brief introduction to Fourier Analysis. (6)

Complex Analysis : Algebra of complex numbers, the complex plane, polynomials, power series. Analytic functions, Cauchy-Riemann equations. Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, Taylor series, Laurent series, calculus of residues. Some special characteristic functions . (15)

### References :

| | | |
|---|---|---|
| T.M. Apostol | : | Mathematical Analysis |
| W. Rudin | : | Principles of Mathematical Analysis |
| R.R. Goldberg | : | Methods of Real Analysis |
| K.M. Hoffman & R.Kunze | : | Linear Algebra (2nd Edition) |
| J.B. Conway | : | Functions of one complex variable |
| R. Courant & F. John | : | Introduction to Calculus and Analysis- Vol. II |
| W. Brown & R.V. Churchill | : | Complex Variables and Applications (8th ed.) |
| G.F. Simmons | : | Introduction to Topology and Modern Analysis |

## STAT 306 : Applied Bayesian Methods (3+1)

Bayesian Linear Regression with Conjugate priors, Bayesian Model Selection, Bayesian Information Criterion.

Monte Carlo Method , Markov chains and MCMC, Gibbs Sampling with  examples  in R and WinBUGS, The Metropolis-Hastings Algorithm.

Generalized linear models and categorical data, longitudinal models, Bayesian multiple imputation.

Bayesian Hypothesis Testing (One-sided and Two-sided Example), The Bayes Factor, A Test for Comparing Two Population Means.

Hierarchical Bayes Examples, Exchangeability, Hierarchical Bayesian Analysis Shrinkage and Bayesian Estimation, Empirical Bayes Estimation (with examples), Comparison of Hierarchical vs. Empirical Bayes.

Bayesian Probit and Logistic Regression (Multi-category Ordinal Response).

Multinomial-Dirichlet model.

Nonparametric Bayes.

### *References :*

| J.O. Berger | : | Statistical Decision Theory and Bayesian Analysis |
| C.P. Robert | : | The Bayesian Choice |
| J.K. Ghosh, M. Delampady & T. Samanta : | | Bayesian Inference |
| P. Lee | : | Bayesian Statistics – An Introduction |

## STAT 307 : Regression Designs (3+1)

| Regression Designs | (10) |
| Optimum Regression Designs | (10) |
| Mixture Experiments | (10) |

### *References:*

| G.E.P. Box & N.R. Draper | : | Empirical Model Building and Response Surfaces |
| A.I. Khuri & J.A. Cornell | : | Response Surfaces |
| V.V. Fedorov | : | Theory of optimal experiments |
| S.D. Silvey | : | Optimal design |
| F. Pukelsheim | : | Optimal design of experiments |
| J. Cornell | : | Experiments with Mixtures |

## STAT 308 : Operations Research (3+1)

| Definition and Scope of Operations Research. | (2) |
| Decision-making under uncertainty and risk, use of different criteria, sensitivity analysis. | (2) |

Analytical structure of inventory problems, EOQ formula of Harris & Wilson, its sensitivity analysis and extensions allowing quantity discounts and shortages. Models with random demand, the static risk model. P and Q- systems with constant and random lead times.  (6)

Queueing models – specification and effectiveness measures. Steady-state solutions of M/M/1, M/M/c and M/M/c/N models, Machine interference problem, Waiting time problems, Little's formula.  (5)

Sequencing and scheduling problem.  (3)

Transportation problem. Stepping stone algorithm. Assignment problem. Hungarian method.  (6)

Replacement problems – Deterministic models, Preventive replacement policies (cost and availability criteria), Staffing Problem  (6)

### *References :*

| | | |
|---|---|---|
| H.A. Taha | : | Operational Research |
| F.S. Hillier & G.J. Leiberman | : | Introduction to 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 |
| I. B. Gertsbakh | : | Reliability Theory with Appl. to preventive maintenance |

## STAT 309 : Demography (3+1)

Use of balancing equation. Population composition-population pyramid.  (2)

Definition of concepts: Life and Death, Death Rates- age, space and cause specific.

Adjusted death rates, Natality: Birth rates- age-sex adjusted, Quality Adjusted Life.  (6)

Migration-related measures.  (2)

Life tables: Distribution of life table functions and their estimates. Multiple Decrement tables.  (6)

Growth curve models, Population Estimation and Projection, Methods for Population projection. Stable and quasi stable population intrinsic growth rate. (6)

Stochastic Models for Social and Occupational Mobility based on Markov Chains – closed and open systems, Estimation of Measures of Mobility. Manpower planning Models. (8)

### References :

| | | |
|---|---|---|
| D.J. Bartholomew | : | Stochastic Models for Social Processes (3[rd]ed.) |
| C.L. Chiang | : | Introduction to Stochastic Processes in Biostatistics |
| P.R. Cox | : | Demography |
| H.S. Shryock et.al. | : | The Methods and Materials of Demography |
| N.Keyfitz & N. Caswell | : | Applied Mathematical Demography |

## Elective - 2

## STAT 310 : Probability III (4+0)

Uniform integrability, applications. (4)

Infinite product spaces, probability measures on infinite products: Kolmogorov's consistency theorem (statement). (4)

Conditional expectations and their properties (with proofs).Regular conditional probabilities and distributions. Sufficiency. Factorization criterion. (12)

Discrete parameter martingales: filtrations, martingales, sub-, super-, reversed martingales, examples, maximal inequality, upcrossings inequality, convergence theorems, closability, stopping times, optional sampling. Applications. (20)

### References :

| | | |
|---|---|---|
| Y.S. Chow & H. Teicher | : | Probability Theory: Independence, Interchangeability, Martingales, 3[rd]ed. |
| S. Resnick | : | A Probability Path,Birkhäuser; 5[th]ed. |
| D. Williams | : | Probability with martingales |

| K.L. Chung | : | A Course in Probability Theory, 3$^{rd}$ed. |
| K. B. Athreya & S. N. Lahiri | : | Probability Theory |
| R.J. Serfling | : | Approximation Theorems of Mathematical Statistics |
| P. Billingsley | : | Probability and Measure |

## STAT 311 :Advanced Sample Surveys  (3+1)

Unified theory of finite population sampling.Sampling design, sampling scheme.Hanurav's unit drawing algorithm, 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.πPS sampling schemes, Rao-Hartley-Cochran strategy.                                                (10)

Non-existence of UMVUE.Existence / Non-existence of UMVLUE of a population total.Concepts of sufficiency and likelihood in survey sampling.Rao-Blackwell theorem and its applications.Murthy's unordering principle.                                        (6)

Inference under super-population models.Optimal design unbiased strategies and optimal linear model unbiased prediction under simple regression models.                (6)

Estimation for domains – issues in small domain estimation.                        (4)

Randomized response techniques.The Warner model and the unrelated question models.
                                                                        (4)

### *References ;*

C.M. Cassel, C.E. Sarndal.& J.H. Wretman : Foundations of Inference in survey Sampling

A. Chaudhuri & R. Mukerjee        :        Randomized Response –theory andtechniques

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

## STAT 312 : Survival Analysis (3+1)

Introduction.Basic functions and Models.Censoring and Truncation.                (5)

Parametric univariateestimation : Standard models – exponential, Weibull, log-logistic, log-normal and Gamma. (2)

Nonparametric univariate estimation : Actuarial, Kaplan-Meier and Nelson-Aalen estimators. (6)

Tests of equality of survival functions :Gehan's and Mantel-Haenszel tests. (3)

Semiparametric regression models :Cox proportional hazard model – estimation, tests, diagnostics. (6)

Additive Models. Accelerated Models (4)

Competing Risk and Multivariate Survival models. (2)

Frailty Models. (2)

### *References :*

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, 2nd ed.

J.P. Klein & M.L. Moeschberger : Survival Analysis : Techniques for Censored and Truncated Data

D.J. Kleinbaum & M. Klein : Survival Analysis – A Self-Learning Text

## STAT 313 : Actuarial Statistics (3+1)

Review of decision theory and actuarial applications.

Loss distributions: modelling of individual and aggregate losses, moments, fitting distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance, share of claim amounts, parametric estimation with incomplete information.

Risk models: models for claim number and claim amount in short-term contracts, moments, compound distributions, moments of insurer's and reinsurer's share of aggregate claims.

Review of Bayesian statistics/estimation and application to credibility theory.

Experience rating: Rating methods in insurance and banking, claim probability calculation, stationary distribution of proportion of policyholders in various levels of discount.

Delay/run-off triangle: development factor, basic and inflation-adjusted chain-ladder method,alternative methods, average cost per claim and Bornhuetter-Ferguson methods for outstanding claim amounts, statistical models.

Review of generalized linear model, residuals and diagnostics, goodness-of-fit, applications.

Review of time series analysis, filters, random walks, multivariate AR model, cointegrated time series, non-stationary/non-linear models, application to investment variables, forecasts.

Assessment of methods through Monte-Carlo simulations.

### References :

N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones & C. J. Nesbitt  :

Actuarial Mathematics, 2nd ed.

S. A. Klugman, H. H. Panjer, G. E. Willmotand & G. G. Venter  :

Loss Models: From Data to Decisions.

C. D. Daykin, T. Pentikainen & M. Pesonen  :  Practical Risk Theory for Actuaries.

## STAT 314 : Optimization Techniques (2+1)

Search methods – different search methods for the single and several variable(s).

Fibonacci, Golden Section, Steepest Descent methods                                    (6)

Integer programming – integer linear and mixed integer linear programming problems, Gomery's cutting plane method, Branch and Bound method. Balas algorithm for zero-one programming,                                                                                (7)

Goal programming – formulation of goal constraints, Partitioning algorithm.          (2)

Non-linear  programming – multivariate optimization with inequality constraints. Kuhn-Tucker conditions. Convex programming, Quadratic Programming – Wolfe's  algorithm. (7)

Dynamic Programming.                                                                       (8)

### References :

G. Hadley                                    :          Linear Programming

| K.G. Murthy | : | Linear and Combinatorial Programming |
|---|---|---|
| S. N.S. Kambo | : | Mathematical Programming Techniques |
| S.S. Rao | : | Optimization – Theory and Applications |
| K.V. Mittal | : | Optimization  Methods |

# Semester IV

## STAT 401 : Stochastic Processes (3+0)

Introduction, Count process. Poisson process. (3)

Renewal Theory: renewal processes, renewal function, elementary renewal theorem, applications, Blackwell's and key renewal theorems (statements), alternating renewal processes, applications to limiting excess and age. (9)

Markov chains: time-homogeneity, one-step & multi-step transition probabilities, Chapman-Kolmogorov equations, Markov times, strong Markov property, classification of states, stationary distributions, periodicity, ergodicity, convergence. Examples: birth-and-death processes, branching processes (12)

Jump-Markov processes: conservativeness, transition probabilities, holding times, embedded Markov chain, Chapman-Kolmogorov equations, Kolmogorov backward and forward equations, stationary distributions. Examples: pure birth, birth-and-death chains. Applications to queueing. (6)

***References :***

| S. Karlin & H.M. Taylor | : | A First Course in Stochastic Processes |
|---|---|---|
| J.  Medhi | : | Stochastic Process |
| D.R. Cox | : | Renewal Theory |
| S. Ross | : | Stochastic Process |
| A.K. Basu | : | Stochastic Process |
| P.G. Hoel, S.C. Port & C.J. Stone | : | An Introduction to Stochastic Process |
| R.N. Bhattacharyya & E. Waymire | : | Stochastic Processes and Applications |

## STAT 402 : Advanced Data Analytic Techniques (3+2)

**Resampling Techniques** (**10**)

Permutation tests (2)

Introduction to Jackknife and Bootstrap-methods for estimating bias, standard error and distribution function based on iid random variables, (3)

Standard examples (3)

Bootstrap confidence intervals (2)

**Missing data analysis (10)**

Informative or non-informative missingness; MCAR, MAR and MNAR. (2)

Complete case / Available case estimation (2)

Mean imputation, Hot and cold deck imputation; MICE. (4)

EM & MCEM algorithms and data augmentation techniques. (2)

**Longitudinal data analysis (10)**

Longitudinal regression : Cohort vs longitudinal effect,  Bias and efficiency (3)

Robust estimation -Weighted least-squares; Robust standard error estimation. (2)

Parametric estimation: ML and REML. (2)

Marginal, subject specific and transition models for continuous, binary and count outcomes. (2)

Concept of GEE. (1)

### *References :*

J.J. Faraway : Linear Models with R

J.J. Faraway : Extending the Linear Model  with R

D. Ruppert et al. : Semiparametric Regression

R.J.A. Little & D.B.Rubin : Statistical Analysis with Missing Data

C.K. Enders : Applied Missing Data Analysis

M.A. Tanner : Tools for Statistical Inference

G.J. McLachlan & T. Krishnan : The EM Algorithm and Extensions

B. Efron & R.J. Tibshirani : An introduction to bootstrap

B.Efron : The jackknife, the bootstrap, and other

| | | resampling plans |
|---|---|---|
| B. Efron | : | Bootstrap methods – another look at jackknife |
| J. Shao & D. Tu | : | The Jackknife and Bootstrap |
| P.J. Diggle et. al. | : | Analysis of Longitudinal Data (2nded). |

## Elective - 3

## STAT 403 : Probability IV (4+0)

Weak convergence of probabilities on Polish spaces: Portmanteau theorem, tightness, Prohorov's theorem. Weak convergence in C([0,1]): co-ordinate process, Arzela-Ascoli theorem, conditions for tightness. (10)

Brownian motion on [0,1], on [0,∞), properties; limit theorems, Brownian bridge, invariance principles. Skorohod's representation.Applications. (20)

Brief introduction to diffusions. (10)

### *References:*

| D. Freedman | : | Brownian motion and diffusions |
|---|---|---|
| P. Billingsley | : | Convergence ofprobabilitymeasures. |
| K.R. Parthsarathy | : | Probabilitymeasures on metric spaces. |
| R.L. Schilling & L. Partzsch | : | Brownian motion. |
| De Gruyter | : | An introduction to stochastic processes |
| P. Mörters & Y. Peres | : | Brownian motion. |

## STAT 404 : Advanced Parametric Inference (3+1)

Invariant statistical decision problem and invariant decision rules.Equivariant estimation. Best invariant estimator in location and scale families. Invariance in hypothesis testing,Uniformly most powerful invariant tests. (8)

Improved estimation of mean and dispersion under the normal set up. (5)

Behrens-Fisher problem and its generalisation.Scheffe's solution in the univariate case and its multivariate extension.Welch's approach.Banerjee's approach. (5)

Multiple Hypothesis Testing (8)

Hypothesis testing problem under order restricted problems (4)

### References :

| E.L. Lehmann & G. Casella | : | Theory of Point Estimation |
| E.L. Lehmann & J.P. Romano | : | Testing Statistical Hypotheses |
| R.J. Serfling | : | Approximation Theorems of Mathematical Statistics |
| R. Muirhead | : | Aspects of Multivariate Statistical Theory |
| Y. Hochberg & A.C. Tamhane | : | Multiple Comparisons Procedures |
| R. Dykstra, T. Robertson & F.T. Wright | : | Advances in Order restricted Statistical Inference |

## STAT 405 : Clinical Trials and Bioassay (3+1)

### Clinical Trials (20)

Introduction, Ethical issues in clinical trials, Types of clinical trials, Sample size determination, Group sequential monitoring. (9)

Randomized clinical trials: Randomization for balancing treatment assignments (random allocation rule, truncated binomial design, biased coin designs), Incorporating covariate information. (7)

Randomization to favor the better performing treatments for binary responses (play-the winner and randomized-play-the –winner rules). (4)

### Bioassay (10)

Logic of biological assay; Dose-response relation; Quantitative and quantal responses; Feiler's theorem for fiducial limit estimation. (2)

Probit and Logit models for quantal assay; Estimation of effective dose levels from symmetric and asymmetric tolerance distribution. (4)

Problems with extreme dose level and Quantit analysis; Acute bioassay. (2)

Pool adjacent violator algorithm and Non-parametric estimation of effective dose levels. (2)

### References :

| S. Piantadosi | : | Clinical Trials - A Methodologic Perspective |
| B.S. Everitt & A. Pickles | : | Statistical Aspects of Design & Analysis ofClinical 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 |
| D.J. Finney | : | Statistical Methods for Biological Assay |
| B.J.T Morgan | : | Analysis of Quantal Response Data |
| Z. Govindarajulu | : | Statistical Techniques in Bioassay |

## STAT 406 : Statistical Quality Management (3+1)

Group control chart. Extreme value chart. Moving average and exponentially weighted moving average charts. Cu-sum charts using V-masks and decision intervals. Economic design of $\overline{X}$ - chart. (8)

Multivariate Control Charts (4)

Acceptance sampling plans for inspection by variables for two-sided specifications. Mil Std 105 plans. Continuous sampling plans of Dodge type and Wald-Wolfowitz type and their properties. Bayesian sampling plans (9)

Process Capability (3)

QM System and ISO 9001 – brief exposition. (2)

Basic concepts of 6s - DMAIC approach and the metrics used. (4)

*References :*

| D.C. Montogomery | : | Introduction to Statistical Quality Control |
| E.R. Ott | : | Process Quality Control |
| G.B. Wetherill | : | Sampling Inspection and Quality Control |
| G.B. Wetherill & D.W. Brown : | | Statistical Process Control – Theory and Practice |

## STAT 407 : Statistical Analysis of Big Data (3+1)

Introduction to Big data. (2)

Generalization of Linear Regression- Ridge Regression, LASSO, Kernel Regression and Principal Components Regression Partial least squares. (7)

Dimension Reduction-Generalization of Principal Component Analysis- Independent
Component Analysis (ICA) and projection persuit. (7)

Generalization of Linear Discriminant Analysis- Two groups: unknown distributions, Nearest
neighbor technique, Evaluating classifiers: ROC Curves. (6)

Tree based methods- Classification and Regression Trees (CART). (6)

Cosmic Microwave Background: Anisotropy, Multiple Testing- Higher Criticism Statistic. (2)

### *References:*

| T. Hastie, R. Tibshirani & J. Friedman | : | The Elements of Statistical Learning |
|---|---|---|
| B.L. Friedman, et al. | : | Classification and Regression Trees |
| A. Hyvarinen, et al. | : | Independent Component Analysis |
| R. Stephen & E. Richard | : | Independent Component Analysis – Principles and Practice |
| R.A. Johnson & D.W. Wichern | : | Applied Multivariate Statistical Analysis |

## Elective - 4

# STAT 408 : Applied Stochastic Models (4+0)

Majorization and stochastic order relations. Applications in Probability, Statistical inference,
Reliability, Economics, and Finance. (10)

Risk-free and risky assets: examples. Present valuation. Valuation by expectation under
risk. (3)

Basic portfolio management, mean-variance efficient frontiers. Utilities, Value-at- risk.
Capital assets pricing models. (4)

Self-financing portfolios in finite markets. Martingales and martingale differences
(definitions and main results without proofs), connections with risk-neutral probabilities.
Fundamental theorems of asset pricing. Basic ideas of replication, hedging. (8)

Pricing of European options. Cox-Ross- Rubinstein Binomial model. Geometric Brownian
motion; Black-Scholes model. Brief mention of exotic options. (5)

### References:

A. W. Marshall, I. Olkin & B. Arnold :     Inequalities: Theory of Majorization and its Applications (2nd ed)

M. Shaked.& J. G. Shantikumar   :      Stochastic Orders

M. Capinski & T. Zastawniak     :      Mathematics for Finance

S. M. Ross     :      An elementary introduction to mathematical finance

D. Kennedy     :      Stochastic Financial Models

S. Resnick     :      A Probability Path

N. Privault     :      Stochastic Finance: An Introduction with Market Examples

A. N. Shiryaev     :      Essentials of stochastic finance: facts, models, theory

## STAT 409 : Nonparametric Methods (3+1)

U-Statistics.     (5)

Linear Rank Statistic and its asymptotic distribution under null and different local lternatives.     (5)

Consistency and Asymptotic Relative efficiency.Optimality of tests.     (3)

Bivariate Sign Test.     (2)

Hodges-Lehmann Esimators and their properties.     (3)

Measures of robustness, sensitivity curves and Influence functions.     (3)

M estimators, breakdown point, Density Estimation.     (6)

Rank Regression.     (3)

### References :

J. Hajek & Z. Sidek     :      Theory of Rank Tests

R.H. Randles & D.A. Wolfe     :      Introduction to the theory of nonparametric statistics

T.P. Hettmansperger     :      Statistical Inference based on ranks

E.L. Lehmann     :      Theory of Point Estimation

P.J. Huber & E.M. Ronchetti     :      Robust Statistics (2nd Ed)..

F.R. Hampel, E.M. Ronchetti, P.J. Rousseeuw & W.A. Stahel.

     : Robust Statistics: The Approach Based on Influence Functions.

R.A. Maronna, R.D. Martin & V.J. Yohai : Robust Statistics: Theory and Methods.

## STAT 410 :Epidemiology (3+1)

Definition of epidemiology. Case study on John Snow and the Lambeth cholera epidemic. Study designs: Ecological, Cross-sectional, Cohort, Case-Control and its variants. Prospective and Retrospective studies. (6)

Standard measures of Disease frequency and association based on rates and proportions. (4)

Confounding and effect modification. (2)

The design and analysis of cohort and case-control studies. (6)

The design and analysis of matched studies. (6)

Concept of causality and its measurement. (3)

Case studies. (3)

### References :

| | | |
|---|---|---|
| K.J. Rothman & S. Geenland | : | Modern Epidemiology |
| S. Selvin | : | Statistical Analysis of Epidemiologic Data |
| D. McNeil | : | Epidemiological Research Methods |
| J.F. Jekel, J.G. Elmore & D.L. Katz : | | Epidemiology, Biostatistics and Preventive Medicine |
| N.E. Breslow & N.E. Day | : | Statistical Methods in cancer Research, Vol. 1, TheAnalysis of Case-Control Studies |
| N.E. Breslow & N.E. Day | : | Statistical Methods in cancer Research, Vol. 2, The Design and Analysis of Cohort Studies |
| S.J. Pocock | : | Clinical Trials |
| J. Whitehead | : | The Design and Analysis of Sequential Clinical Trials |

## STAT 411 : Reliability Analysis (3+1)

Reliabilty concepts and measures, components and systems, coherent systems, reliability of coherent systems. (4)

Life-distributions, reliability function, hazard rate, Mean residual life, common univariate life distributions – exponential, weibull, gamma, etc..Bivariate exponential. (6)

Notions of ageing – IFR, IFRA, NBU, DMRL and NBUE classes and their duals, preservation of such classes under reliability operations, Loss of memory property,Partial ordering of life distributions. (6)

Reliability estimation based on failure times from variously censored life-tests data for parametric families. (4)

Kaplan – Meier estimation of reliability curve, Greenwood formula, Non – parametric methods for comparison of several reliability curves, Log rank tests. (5)

Regression models in reliability, Cox PH and Accelerated failure time models; Estimation of parameters and diagnostics. (5)

### *References:*

R.E. Barlow & F. Proschan  :      Statistical Theory of Reliability and Life- Testing

J.F. Lawless                    :         Statistical Models and Methods of Life-time data

L.J. Bain & M. Engelhardt  : Statistical Analysis of Reliability and Life- testing Models

S. Zacks      : Introduction to Reliability Analysis: Probability Models and Statistical Methods

J.D. Kalbfleisch &R.L. Prentice :   The Statistical Analysis of Failure time data, 2nded.

P.J. Smith                      :         Analysis of failure and survival data

C.D. Lai & M. Xie            :         Stochastic Ageing and Dependence for Reliability

I.B. Gertsbakh              :   Reliability Theory with Applications to Preventive maintenance

## STAT 412 : Directional and Spatial Statistics (3+1)

Examples of Directional Data (DD) in Astronomy. (2)

Graphical representations and Summary measures. (3)

Characterizations and Constructions of probability distributions on the circle and sphere. (7)

Statistical inference in one and several von Mises populations. (6)

Circular Goodness-of-Fit tests. (2)

Tests for complete spatial randomness. (3)

Theory of Spatial point process and spatio-temporal point process. (4)

Spatial cross correlation.                                                                    (3)

### *References:*

| | | |
|---|---|---|
| N.I. Fisher, et al. | : | Statistical Analysis of Spherical Data |
| S.R. Jammalamadaka & A. SenGupta. | : | Topics in Circular Statistics |
| K.V. Mardia. | : | Statistics of Directional Data |
| G.S. Watson. | : | Statistics |
| G.L. Gaile & J.C. Willmott | : | Spatial Statistics and Models |
| N. Cressie | : | Statistics for Spatial Data |

<h3 align="center">Elective - 5</h3>


# STAT 413 : Sequential and Semiparametric Methods (3+1)

### Sequential Methods (20)

Generalised Behrens Fisher problem, Fixed width interval estimation, Partial Sequential tests.

### Semiparametric Models and their Analyses (10)

Single-Index-Models.Generalised Partial Linear Models.Generalized Additive Models. Different types of likelihood functions. Categorical data and related tests of significance.

### *References :*

| | | |
|---|---|---|
| Härdle, Müller, Sperlich & Werwatz | : | Non- and SemiparametricModelling |
| D.Ruppert, M.P. Wand and R.J. Carroll | : | Semiparametric Regression |
| W. Härdle | : | Applied Nonparametric Regression |
| P.J. Green and B.W. Silverman | : | Nonparametric Regression & Generalized Linear Models |
| J.L. Horowitz | : | Semiparametric methods in Econometrics |
| T. Hastie and R. Tibshirani | : | Generalized Additive Models |
| P. McCullagh and J. Nelder | : | A Generalized Linear Models, 2 edn, |
| D.W. Scott | : | Multivariate Density Estimation:Theo., Prac. & Visualization |
| M.P. Wand and M.C. Jones | : | Kernel Smoothing |
| A. Yatchew | : | Semiparametric Regression for Applied Econometrician |
| D. Sigmund | : | Sequential Inference |
| J. Berger | : | Statistilca Decision Theory - Foundation, Concepts & Methods |

B.K. Ghosh                :         Sequential Tests of Statistical Hypotheses

## STAT 414 : Econometrics (3+1)

Single-equation models – censored data, measurement errors, lagged variables. (7)

Simultaneous Equations – identification & estimation. SUR models. (12)

Analysis of Panel Data (5)

Granger causality, Exogeneity testing. Error Correction Model. (4)

Cointegration. (2)

### References :

| | | |
|---|---|---|
| J. Johnston | : | Econometric Methods |
| G.G. Judge, et.al. | : | The Theory and Practice of Econometrics (2$^{nd}$ed.) |
| W. Greene | : | Econometric Analysis |
| E. Malinvaud | : | Statistical Methods in Econometrics |
| B.M. Baltagi | : | Econometric Analysis of Panel Data |
| M.D. Intrilligator, R.G. Bodkin & C.Hsiao : | | Eco. Models, Techniques and Applications |
| G.S. Maddala& I.M. Kim | : | Unit Roots, Cointegration, and Structural Change |

## STAT 415 : Statistical Genetics (3+1)

Introduction to genetics (5)

Gene mapping, sequence data, population genetics and coalescent theory (7)

Phylogeny reconstruction (2)

Pedigree analysis (3)

Familial aggregation, segregation and linkage and association (6)

Genetic epidemiology, role of genetic factors in human diseases (4)

Analysis of complex and quantitative traits (3)

### References

B.H. Liu          :         Statistical Genomics Linkage, Mapping, and QTL Analysis

B. Neale, M. Ferreira, S. Medland & D. Posthuma (eds.)

            : Statistical Genetics: Gene MappingThrough Linkage and Association

| N.M. Laird & C. Lange | : | The Fundamentals of Modern Statistical Genetics |
| M. Lynch & B. Walsh | : | Genetics and Analysis of quantitative traits. |
| J. Felsenstein | : | Inferring Phylogenies |
| Z. Yang | : | Computational Molecular Evolution, Oxford University Press |

## STAT 416 : Advanced Operations Research (3+1)

P, Q systems – exact analysis. Inventory of deteriorating items.  Models with price inflation, sequential inventory model.                                                                 (7)

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 $2 \times 2$, $2 \times m$ and $m \times n$ games. Non-zero-sum game.                                            (6)

M/G/1 queue and Pollazcek-Khinchine result. Steady-state solutions of $M/E_k/1$ and $E_k/M/1$ queues, Bulk arrival and bulk service queues.                                                (7)

Traveling salesman problem - Branch and Bound method, Simulated annealing.        (4)

Project management and Network analysis - PERT and CPM, Different time estimates - slack time, critical path, LP formulation of network problems, crashing of activities, Flow along network, Ford – Fulkerson's algorithm, Dijkstra's algorithm.                     (6)

### *References :*

| H.A. Taha | : | Operational Research |
| F.S. Hillier & G.J. Leiberman | : | Introduction to 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 |
| R. V. Hartley | : | Operations Research – A Managerial Emphasis |

## STAT 417 : Astrophysics and related data sources (3+1)

 Basic Background: Elementary radiative transfer equations, absorption and emission, atomic processes. Distance measurement in Astronomy. Hubble's law.                     (8)

Spectral Classification of Stars: Saha's equation, Harvard System, Absolute and apparent magnitude, Mass luminousity relation, Parallax. (5)

Stellar Structure, Polytropic and homologous models Evolution of Stars: Observational basis, Sources of stellar energy, Hertzsprung-Russell diagram, evolution of low and high mass stars, Chandrasekhar limit. (5)

Stellar populations- Galactic and Globular Clusters. (2)

Galaxies- Classification-surface brightness profile-fundamental plane and its significance-Rotation curves-Missing mass and dark matters. (4)

Astronomical Measurement Errors: Statistical issues and problems. (4)

Data archives and Virtual Observatories. (2)

### *References:*

G.J. Babu & E.D. Feigelson      :      Astrostatistics

K.D. Abhyankar      :      Astrophysics: Stars and Galaxies

A.N. Cox      :      Astrophysical Quantities

W.R. Oegerie & M.J. Fitchell      :      Clusters of galaxies

B. Basu et al.      :      An Introduction to Astrophysics