**Choice Based Credit SystemCore Courses**

**School of Statistics,DAVV for courses 2019- 2021**

**Section 1**

The syllabus modified in 2019 has already made provisions for CBCS in the following manner:

1. C programming : Enabling an exposure to other discipline and providing an expanded scope for computation based research
2. Other core courses are mentioned in section 2

Elective Courses: courses are mentioned in section 2 with \*

1. Real analysis: Providing an expanded scope for students wishing to appear for NET examinations as a major part of NET syllabus comprises of mathematics courses.
2. Econometrics
3. PIE
4. Operations Research (i)
5. Operations Research (ii)

iv,v,vi,vii above are all elective papers intended towards Enabling an exposure to other discipline and supportive to discipline of study

1. Word and EXCEL: Nurturing students’ proficiency/ soft skill and providing an expanded scope for corporate jobs.

Following is the relevant excerpt from the syllabus modified in Jan 2014 by the Board of Studies in statistics:

**Nomenclature:**

CB: Choice Based for SOSTAT students;

O: May be opted for study by students of other departments ( Depending upon availability of space and faculty)

C: Core course for SOSTAT students

G: generic course for SOSTAT students.

**Semester I (Total valid credits = 24)**

Paper Code Title of the Paper Credits Nomenclature

|  |  |  |
| --- | --- | --- |
| |  |  | | --- | --- | | SOSTAT  Students | Students of  other departments | |
| |  |  | | --- | --- | | **C** | **NA** | | **CB** | **NA** | | **C** | **O** | | **C** | **O** | | **CB,G** | **O** | | **C** | **NA** | |

ST5A – 501 : Measure and Probability Theory 4

ST5A T – 503 : Linear algebra \* 4

ST5A – 505: Distribution Theory 4

ST5A - 507 Statistical methods 4

ST5A – 509 : Statistical Computing \* 4

ST5A – 511: Practical paper 4

(Practical paper is based on the contents of Papers ST5A – 501. ST5A – 503, ST5A – 505 and ST5A – 507)

ST5A –551: Comprehensive Viva-voce 4

**SEMESTER II : (Total Valid credits = 24)**

4 Theory papers of 4 credits each : Total 20 credits

1 Practical of 6 credits : Total 6 credits1 Comprehensive viva voce Examination of 4 virtual credits: Total 4 credits

The courses to be covered in this semester are:

|  |  |  |
| --- | --- | --- |
| |  |  | | --- | --- | | SOSTAT  Students | Students of  other departments | |
| |  |  | | --- | --- | | **C** | **NA** | | **C** | **NA** | | **C** | **NA** | | **CB,G** | **O** | | **C** | **NA** | | **C** | **NA** | |

Departmental Core Courses ( Compulsory papers ) :

Paper Code Title of the Paper Credits

**ST5A** -502: Sample Surveys and Indian Official Statistics 4

ST5A –504: Stochastic Processes 4

ST5A – 506: Statistical Inference - I 4

ST5A – 508: Word Processing Through MS Word and Spreadsheets: MS Excel\* 4

ST5A – 510: Multivariate Analysis 4

ST5A –512: Practical Paper 4

(based on the contents of Papers **ST5A** -502 6, **ST5A** -504, **ST5A** -506 and **ST5A** -508)

ST5A –552: Comprehensive Viva-voce 4

**SEMESTER III : (Total valid credits = 22)**

4 Theory papers of 4 credits each : Total 16 credits

1 Major Project of 6 credits : Total 6 credits

1 Comprehensive viva voce Examination of 4 virtual credits: Total 4 credits

The courses to be covered in this semester are:

Departmental Core Courses( compulsory papers ):

|  |  |  |
| --- | --- | --- |
| |  |  | | --- | --- | | SOSTAT  Students | Students of  other departments | |
| |  |  | | --- | --- | | **C** | **NA** | | **CB** | **O** | |  |  | | **CB,G** | **O** | | **CB,G** | **O** | | **C** | **NA** | |

Paper Code Title of the Paper Credits

ST 5A– 601 Statistical Inference II 4

ST 5A –603 Design and Analysis of Experiments 4

**Major Elective Courses :**

ST 5A – 605 Operations Research (i)\* 4

ST 5A – 607 Statistical process and Quality Control \* 4

ST 5A – 609 Project involving: Statistical techniques/Operations research/ Computer software/Programming 6

ST5A –651: Comprehensive Viva-voce 4

**SEMESTER IV : (Total credits = 22)**

4 Theory papers of 4 credits each : Total 16 credits

1 Major Project of 6 credits : Total 6 credits

1 Comprehensive viva voce Examination of 4 virtual credits: Total 4 credits

The courses to be covered in this semester are :

|  |  |  |
| --- | --- | --- |
| |  |  | | --- | --- | | SOSTAT  Students | Students of  other departments | |
| |  |  | | --- | --- | | **C** | **NA** | | **CB,G** | **MA** | | **CB,G** | **NA** | | **CB,G** | **O** | | **C** | **NA** | | **C** | **NA** | |

**Major Elective Courses** : Paper Code Title of the Paper Credits

ST 5A – 602 Linear Models and Regression Analysis 4

ST 5A –604 Econometrics\* 4

ST 5A –606 Operations Research (ii)\* 4

ST 5A – 608 Planning and Analysis of Industrial Experiments \* 4

ST 5A **-** 610 **Real Analysis \* 4**

ST 5A – 612- Project involving: Statistical techniques/Operations research/Computer software/Programming 6

ST5A –651: Comprehensive Viva-voce 4

**ST5A- 501 Measure And Probability**

Classes of sets, fields, fields, minimal fields, Borel fields In Rk , sequence of sets, limSup and limInf of sequence of sets, (8 L)

Measure , Carathedeory extension theorem(statement only), Lebesgue and Lebesgue Steiltjes measures on Rk. Properties of measure, Probability measure, Classical, statistical and axiomatic definitions of Probability, compound Probability, additive, multiplicative and other important theorems (of probability) and their applications. Conditional probability, Baye’s theorem, their applications, Independence of events. (15 L)

Measurable functions, random variables, distribution functions, Independence of random variables, sequence of random variables, almost sure convergence, convergence in probability, integration of a measurable function with respect to a measure, monotone convergence theorem, Fatou’s lemma, dominated convergence theorem.(10 L)

Convergence in distribution, Cramer and Slutsky's Theorems.

Characteristic function, uniqueness theorem, Levy's continuity theorem ( statement only ), Inversion theorem and applications based on them. (6 L)

Borel- Cantelli Lemma, Weak law and strong law of large numbers, (6)

CLT for sequence of independent random variables under Linderberg’s condition, CLT for iid random variables. (6 L)

**Reference:**

Bhat, B.R. : Modern probability Theory, New Age Publishers

Rohatgi, VK. .(1984) : An Introduction to Probability Theory And Mathematical Statistics, Wiley Eastern.

**Additional References:**

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

Dudley, R. M. (1989). Real Analysis and Probability, Wadsworth and Brooks/Cole. Cambridge University Press.

Basu, A. K. (2003) : Measure theory and probability. PHI.

**ST5A - 503 Linear Algebra**

Vector space and subspaces, linear dependence and independence, basis and dimension of a vector space, finite dimensional vector spaces, completion theorem, examples of vector spaces over real and complex fields, linear equations. (5 L)

Vector spaces with an inner product, Gram-Schmidt ortf301hogonalization process, orthonormal basis and orthogonal projection of a vector (5 L)

Liner transformations, algebra of matrices, row and column spaces of a matrix, elementary matrices, determinants, rank and inverse of a matrix, null space and nullity, partitioned matrices, Kronecker product. (4 L)

Hemite canonical form, generalized inverse, Moore-Penrose generalized inverse, idem potent matrices, solutions of matrix equations. (6 L)

Real quadratic forms, reduction and classification of quadratic forms, index and signature, triangular reduction of a positive definite matrix. (6 L)

Characteristic roots and vectors, Cayley-Hamilton theorem, minimal polynomial, similar matrices, algebraic and geometric multiplicity of a characteristic root, spectral decomposition of a real symmetric matrix, reduction of a pair of real symmetric matrices, Hermitian matrices. (6 L)

Singular values and singular value decomposition, Jordan decomposition, extreme of quadratic form, vector and matrix differentiation. (8 L)

References

Graybill, F.A.(1983), matrices with application and statistics, second edition, Wadsworth

Rao, C.R.(1973), Linear Statistical Inference and its application, second edition. John Wiley and Sons, Inc.Scarle, S.R.(1982), Matrix Algebra useful for Statistics, John Wiley and Sons, Inc.

Additional References

Bellman, R. (1970) Introduction to Matrix Analysis, Second Edition. McGraw Hill Biswas, S.(1984), Topics in Algebra of Matrices. Academic Publications. Hadley, G.(1987). Linear Algebra, Narosa Publishing House

Halmos, P.R.(1958), Finite Dimensional Vector Spaces, Second Edition, D.Van Nostrand Company, Inc.

Hoffman, K. and Kunze, R.(1971), Linear Algebra , Second Edition, Prentice Hall, Inc.

Rao, A. R. and Bhimasankaram, R(1992) Linear Algebra, Tata Mcgraw Hill Publishing Company Limited.

Rao, C. R. and Mtra, S.K.(1971) Generalized Inverse of Matrices and its Applications, John Wiley and Sons, Inc.

**Practicals**: Ranks,Finding Eigenvalues Eigenvectors, Quadratic forms,Linear transformations,Orthogonal transformation, Gram Schmidt Orthogonalisation, Finding G Inverse, Solving system of Linear Equations.

**ST5A - 505 Distrution Theory**

Distribution: function pdf, pmf, mgf, pgf, cgf, joint, marginal and conditional distribution, Compound, truncated and mixture distribution, conditional expectation independence of random variables, functions of random variables and their distributions using jacobian of transformation and other tools, convolutions. (15)

Expectation, Markov, Holder, Jensen and Liapunov inequalities. (4)

Sampling distributions. Distribution of sum of iid random varribles. Distribution of sample mean and

variance for random samples form bivariate normal distribution, Chi-square, t-and F-distributions and their properties. Tests of hypotheses based on them. Non central - Chi-square, t-and F-distributions. (15)

Order statistics – their distributions and properties. Joint and marginal distributions of order statistics. Distribution of median, range etc., Extreme values and their asymptotic distributions (Statement only ) with Applications. Approximating distributions of sample moments. (10)

REFERENCES

Dudewicz, E.J. and Mishra, S.N.(1988): Modern Mathematical Statistics, Wiley, lnt’l Students’ Edition. Rohatgi, VK. .(1984) : An Introduction to Probability Theory And Mathematical Statistics, Wiley Eastern. Mukhopadhyay. P. Mathematical Statistics P. ,Books & Allied (P)

Mood A., Graybill ,I and Boes, D.C., Introduction to the Theory of Statistics, McGraw Hill, Kogakusha, Int Student Edition

Goon, A.M., Gupta, M.K., Dasgupta, B., An Outline of statistical Theory Vol I and Vol II: World Press

S.C.Gupta And V.K. Kapoor: Fundamentals Of Mathematical Statistics

ADDIIIONAL REFERNCES

Rao, C.R. (1973): Linear Statistial Inference and Its Applications, 2/e, Wiley Eastern. Pitmam J. (1993): Probability, Narosa Publishing House,

Johnson, S. and Kotz, (1972): Distributions in Statistics, Vol. I, II and III, Houghton and Miffin, Cramer H. (1946), Mathematical Methods of Statistics, Princeton.

**Practicals**: Large sample tests, Tests of significance based on chi-square , t, F, z distribution

**ST5A -507 Statistical Methods**

Review of basic statistical methods: Frequency distributions, Measures of location, dispersion,

skewness and kurtosis, factorial and absolute moments, Bivariate frequency distributions. (8)

Method of least squares, Curve fitting: linear, non-linear and curvilinear, Orthogonal polynomials.

Regression and correlation. Product moment correlation coefficient, correlation index, correlation

ratio, intra-class correlation coefficient, Measures of association and contingency. (12)

Discrete distributions: degenerate, Bernoulli, Binomial, Poisson, Geometric, Negative binomial,

hypergeometric, uniform, Multinomial distribution and its marginal and conditional distributions.(12)

Continous distributions : Uniform, Normal, Lognormal, Exponential, Laplace, Pareto, Beta, Gamma,

Cauchy. (12)

Fitting of commonly used discrete and continuous distributions. (4)

**REFERENCES:**

An Introduction to probability and Statistics: Rohtagi, V.K.

Fundamentals of Statistics Vol. I : Goon Gupta and Dasgupta

Fundamentals of Mathematical Statistics: Kapoor, V.K. and Gupta, S.C. Sultan Chand & Sons,

Mathematical Statistics : Mukhopadhyay, P. Books & Allied (P) Ltd.

ADDITIONAL REFERENCES

Pitman, J. (1993) : Probability, Narosa Publishing House,Johnson, S. and Kotz, (1972): Distributions in Statistics, Vol. I,II and III, Houghton and Miffin.

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

**Practicals**: Graphical Techniques and measures of central tendency, dispersion, skewness and kurtosis.Methodof least squares, Curve fitting: linear, non-linear and curvilinear, Orthogonal polynomials. Regression and correlation. correlation index, correlation ratio, intra-class correlation coefficient, Measures of association and contingency. Fitting of distributions: Binomial, Hypergeometric, Poisson, Normal,Exponential,

**ST5A -509 : Statistical Computing**

Programming in a high level language such as C ( or C++) . The purpose of this unit is to introduce programming with the eventual aim of developing skills required to write statistical software Should there be previous exposure to programming, this unit can be replaced by a more advanced unit in object-oriented programming in C + + or Java. Topics should include simple svntax, loops pointers and arrays functions, input/output, and linking to databases. (25)

Numerical analysis and statistical applications. The purpose of this unit is to apply programming skills in methods and algorithms useful in probability, statistics and data analysis, Topics should include numerical integration, root extraction, random number generation, Monte Carlo integration, and matrix computations, Should these be previous exposure to numerical analysis, more advance techniques such as permutation tests and simulation of Poission processes can be presented. (10)

A statistical package such as MINITAB, SAS OR SPSS. The purpose of this unit is to use a statistical package to carry out statistical procedures already known to students. No new statistical methods should be presented but interesting data can be analyzed using known methods on the package. Topics should include graphics, descriptive statistics representation of multivariate data, simple hypothesis tests, analysis of variance, and linear regression. (5)

REFERENCES

B.W.Kernighan and D.M. Ritchie (1988): The C Programming Language, Second Edition, Prentice Hall.

W.H. Press, S.A. Teukolsky, W.T. Vellering, and B.P. Flannery (1993), Numerical Recipes in C, Second Edition. Cambridge University Press.

B. Ryan and B.L. Joiner (2001): MINITAB Handbook, Fourth Edition, Duxbury. R.A. Thisted (1988). Elements of Statistical Computing Chapman and Hall.

Note on suggested books : The choice of textbooks and references depends on the programming language and statistical package used. The above assumes C and MINITAB.

**Practicals**: Programming through C for the practicals mentioned in ST 103,104,102 and for numericaltechniques(numerical integration, differentiation , finding roots of equations, search and sort

techniques. measures of central tendency, dispersion, skewness and kurtosis. Fitting of distributions: Binomial, Hypergeometric, Poisson.

**ST5A - 502 Sample Surveys and Indian Official Statistics**

**A Sample surveys:**

Review of basic finite sampling techniques [SRSWR/WOR, Stratified, Systematic] and related result on estimation of population mean/total, allocation problem in stratified sampling (10)

Unequal probability sampling: PPSWR/WOR methods [including Lahiri’s scheme] and related estimators of a finite population mean [Hansen-Hurwitz and Desraj estimators for a general sample size and murthy’s estimator for a sample of size 2] (10)

Ratio and regression estimators based on SRSWOR method of sampling. Two stage sampling with

equal number of second stage units. Double sampling. Cluster sampling. (10)Randomized response technique [Warner’s model: related and unrelated questionnaire methods] (5)

Indian Official Statistics and its use and applications in various fields viz Agriculture, Industry etc.; Census (6)

REFERENCES

Chaudhuri, A. and Mukherjee, R.(1988) Randomized response: Theory and techniques, New York: Marcel Dekker Inc.

Cochran, W. G.: Sampling techniques [3 rd edition,(1977)],Wiley

Desraj and Chandak (1998): Sampling theory, Narosa

Murthy, M.N.(1977) : Sampling theory & methods, Statistical publishing society. Calcutta Sukhatme et al (1984), Sampling theory of surveys with applications. Iowa state University press &

IARS

Singh, D and Chaudhary, F.S.(1986), Theory and analysis of sample survey design. New Age international Publishers.

**Practicals** : SRSWR/WOR, Stratified, Systematic-- Finding mean, variance, Allocations(for stratifiedsampling). Sample size determination.

**B Official Statistics: (10L)**

Population growth, Economic development, Indices of development, Human development indices, Measuring inequality in incomes, Gini Coefficient, Poverty measurement, different issues, estimation of national income- product approach, income approach and expenditure approach, GDP

Reference:

CSO(1980) National Accounts Statistics – Sources and health

UNESCO: Principles of Vital Statistics Systems Series M-12

Ministry of Statistics and Program Implementation Website: MOSPI.nic.in

**ST5A -504:Stochastic Processes**

Introduction to stochastic processes (sp’s) classification of SP’s according to state space and time domain. Countable state markov chains (ms’s), Chapman- kolmogrov equations; calculations of n-step transition probability and its limit. Stationary distribution, classification of states; transient MC; random walk and gambler’s ruin problem; application from social, biological and physical sciences. (10)

Branching process: Galton- Watson branching process, probability of ultimate extinction, distribution of population size. Martingale in discrete time. Statistical inference in MC and Markov processes. (10) Discrete state space continuous time MC: Kolmogrov-Feller differential equations; Poisson process, birth and death process; Applications to queues and storage problems. Wiener processes as a limit of random walk; first passage time and other problems. (15)

Renewal theory elementary renewal theorem and application and uses of key renewal theorem, study of residual lifetime process. (10)

Stationary process: weakly stationary and strongly stationary processes; moving average and auto regressive processes. (5)

REFERENCES

Adke, S.R. and Manjunath, S.M. (1984): An introduction to Finite Markov processes, Wiely Eastern.

Bhat, B.R. (2000) Stochastic Models: Analysis and Applications, New age International, India. Ross, S. Introduction to Probability Model, Elsevier Publication.

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

Feller, W. (1968): Introduction to Probability and its Applications Vol. 1, Wiely Eastern. Harrils, T.E. (1963): The Theory of Branching Process, Springer Verlag.

Hoel, RG, Port, S.c. and Stone, C.J. (1972): Introduction to Stochastic Processes, Houghton Miffin & Co.

Jagers, P.(1974): Branching Processes with Biological Applications, Wiley.Karlin, S. and Taylor, H.M. (1975): A first course in Stochastic Processes, Vol. 1, and Academic Press

Medhi, J. (1982): Stochastic Processes, Wiley Eastern.

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

**ST5A- 506 : Statistical Inference - I**

Parametric models: Estimation

Point estimation:

Properties of a good estimator: Unbiased, consistent, efficient , sufficient estimators. Consistent

Estimation of real and vector valued parameter., Extension to multiparameter exponential family,

Examples of consistent but not asymptotically normal estimators from Pitman family.

Consistent Asymptotic Normal (CAN) estimator, lnvariance of CAN estimator, Mean squared error

criterion, (10)

Information in data about the parameters as variation in Likelihood Function, concept of no

information, Sufficiency, Neyman Factorizability Criterion, Likelihood Equivalence, Minimal

Sufficient Statistic, Exponential families and Pitman Families, Fisher information for one and

several parameters models. Minimum variance unbiased estimators, Rao - Blackwell Theorem,

completeness, Lehmann - Scheffe theorem, necessary and sufficient conditions for MVUE, Cramer

– Rao lower bound approach. One parameter exponential family. (15)

Interval estimation: confidence level, construction of confidence interval using pivots, confidence

intervals based on CAN estimators shortest expected length confidence interval, uniformly most

accurate one sided confidence interval (5)

Methods of estimation :

Method of maximum likelihood, Likelihood Function, Examples from standard discrete and continuous models (such as Bernoulli, Poisson, Normal, exponential, Gamma, Pareto etc.) Solution of likelihood equations, Method of scoring, Newton - Raphson and other iterative procedures, MLE in Pitman family and Double

Exponential Distribution, Properties of M.L. estimators. Other methods of estimation: Methods of

moments and percentiles, (15)

CAN property of estimators obtained by methods of moments ,percentiles and MLE method in one parameter exponential family, Cramer family, Choice of estimators based on unbiasedness, minimum variance, mean squared error, (5)

REFERENCES

Kale, B. K. (1999) A first Course on Pararnetric Inference, Narosa Publishing House.

Rohatgi V. (1988). An Introduction to Probability and Mathematical Statistics. Wiley Eastern Ltd.

New.Delhi (Student Edition)

ADDITIONAL REFERENCES

Lehmann E. L. (1986) - (Latest) Theory of Point.Estimation (Student Edition) Rao, C. R. (1 973) : Linear Statistical Inference.

Dudewicz, E. J. and Mishra, S. N. (1988). Modern Mathematical Statistics. Wiley Series in Prob. Math. Stat., John Wiley and Sons, New York (Internatioai Student Editinn)

Zacks, S. (1971). Theory of Statistical Inference, John Wiley and Sons, New York.

**Practicals**: Finding Estimators using M.L.method, method of moments, Confidence intervals,Comparison of efficiency of estimators

**ST5A -508 Word Processing Though MS-Word and Introduction to spreadsheets:**

INTRODUCTION TO SPREADUCTION TO SPREADSHEET: MS EXCEL Worksheet basics

Getting started ,Entering information in a worksheet , Enter the heading information as text

Entering data , Entering text , Entering dates, Saving worksheet ,Quitting a worksheet , Closing a worksheet

Opening a worksheet and moving around, Steps to select cells in a worksheet, Steps to select multiple cells in a worksheet

Range: Selecting, naming and using data ranges in a worksheet Toolbars: Standard and formatting toolbar Using toolbars, Changing font size and style, displaying the current format Using menus, Using keyboard shortcuts

**Worksheet Functions :**

Arrays (10 L) ( Matrix operations, Frequency distribution from raw data, Fitting of commonly used statistical distributions, correlation, etc)

Editing data in a cell: Copying entries, Using shortcuts menus Editing and copying formulae .Absolute and relative cell references. Creating, Labeling, Editing,, formatting and printing a work sheet.

Creating and editing graph from worksheet, changing scales, adding background grids, Fitting of least squares curve, Managing use of more than one worksheet, workbook.

Use of spreadsheets for statistical analysis : Presentation, graphical analysis, and regression analysis. Pivot Tables ,tests of statistical hypotheses (10 L)

**Word Processing Package MS-Word (Latest Version)**

Basics :

Introduction to word Processing : Creating Documents , Saving documents , Quitting Documents Printing a document, Editing , formatting ,merging documents. Mail Merge.

**Microsoft OFFICE 2000—GINI COUMRTER and Annette Marquis, BPB publications**

**MS WORD-2000 Thumbrules and Details — S. Banerjee, New Age International Publishers**

**ST5A - 510: MULTIVARIATE ANALYSIS**

Multivariate normal distribution, marginal, conditional distributions, properties, characteristic function. Random sampling from a multivariate normal distribution. Maximum likelihood estimators of parameters. Distribution of sample mean vector. `(10 L)

Wishart Matrix-Its distribution and properties. Distribution of sample generalized variance. Null and non-null distribution of simple correlation coefficient. Null distribution of partial and multiple correlation coefficients. Distribution of sample regression coefficients. Application in testing arid interval estimation. Application in testing and interval estimation. (10 L)

Null distribution of Hotelling’s T2 statistic. Application in tests on mean vector for one and more multivariate normal populations and also on equality of the components of a mean vector in multivariate normal populations. (8 L)

Multivariate linear regression model -Estimations of parameters, test of hypotheses about regression coefficients. Likelihood ratio test criterion. Multivariate analysis of variance [MANOVA] of one-and

two way classified data. (8 L)Classification and discrimination procedures for discrimination between two multivariate normal

populations – Sample discriminant function, tests associated with discriminant functions, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations. (6 L)

Principal components, dimension reduction, canonical variable and canonical correlation –definition, use estimation and computation. (6 L)

Reference

Anderson, T, W. (1983): An Introduction to Multivariate Statistical Analysis.2nd Ed. Wiley. Giri, N.C. (1977): Multivariate Statistical Inference. Academic Press.

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

Morrison, D.F. (1976): Multivariate Statistical Methods 2nd edition, McGraw Hill Muirhead, R.J. (1982) Aspects of Multivariate Statistical Theory. J Wiley

Rao, C.R. (1973) Linear Statistical Inference and its application 2nd Edition. Wiley Seber, G.A.F. (1984): Multivariate Observations, Wiley

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

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

Johnson, R.and Wychern (1992): Applied Multivariate Statistical Analysis, Prentice – Hall, 3rd Ed.

**Practicals**: Fitting of Multivariate normal distribution. Marginal and conditional distributions.

Hotelling’s T2 statistic, , tests associated with discriminant functions, probabilities of misclassification

and their estimation, classification into two and three multivariate normal populations. Principal

components, dimension reduction, canonical variable and canonical correlation

**ST5A- 601 Statistical INFERENCE - II**

**Tests of Hypotheses**

Concepts of critical regions, test functions, two kinds of errors, size function, power function, level, MP and UMP test in class of size alpha tests. Connection of test of hypotheses with interval estimation (8 L)

Neyman - Pearson Lemma, MP test for simple null against simple alternative hypothesis. UMP tests for simple null hypothesis against one sided alternatives and for one sided null against one sided alternatives in one parameter exponential family. Extension of these results to Pitman family when only upper or lower end depends on the parameter and to distributions with MLR property, non-existence of UMP test for simple null against two sided alternatives in one parameter exponential family. (14 L)

Likelihood Ratio Test (LRT), Asymptotic distribution of LRT statistic, Wald Test, Rao's score test, Pearson Chi2 test for Goodness of fit, Bartlett's Test for homogeneity of variances.

Variance stabilizing transformation and large sample tests. (10)

Error probabilities, Minimum sample size required to attain given level of accuracy. (4 L)

**Non Parametric Tests:** .( Emphasis will be more on concepts and applications)

Testing of hypotheses under nonparametric setup. Review of single sampling problems(Tests of randomness, tests of goodness of fit, the problem of location). (8)

Two sample problems: Sign test, Wald Wolfowitz run test. Mann Whitney Wilcoxon test, median

test, K-S test, Kendall’s Tau, Rank Correlation, Kruskal Wallis test, Friedman’s two way ANOVA by ranks , Asymptotic relative efficiency, (12)

REFERENCES

Kale, B. K. (1999) A first Course on Parametric Inference. Narosa Publishing House.

Rohatgi V. (1988). An Introduction to Probability and Mathematical Statistics. Wiley Eastern Ltd. New Delhi (Student Edition)

Gibbons J.D. (1971) non Parametric Inference, McGraw Hill Mukhopadhyay, P.(2002) Mathematical Statistics, Books and Allied (P)

ADDITIONAL REFERENCES

Lehmann, E. L. (1986). Testing Statistical hypotheses (Student Edition)

Rao, C. R. (1973) : Linear Statistical Inference.

Dudewicz. E, J. and Mishra, S. N. (1988). Modern Mathematical Statistics,. Wiley Series in Prob.

Math.,Stat , John Wiley and Sons, New York (International Student Edition)

Ferguson, T, S. (1996). A course on Large Sample Theory. Chapman and Hall, London.

**ST5A- 603: DESIGN AND ANALYSIS OF EXPERIMENTS**

Introduction to designed experiments; General block design and its information matrix (C), criteria for connectedness, balance and orthogonality; Intrablock analysis (estimability, best point estimates/interval estimates of estimable linear parametric functions and testing of linear hypotheses); BIBD- recovery of interblock information; Youden design - intrablock analysis.

Analysis of covariance in a general Gauss-Markov model, applications to standard designs. Fixed, mixed and random effects models,- Variance components estimation - study of various methods; Tests for variance components; Missing plot technique- general theory and applications.

General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects; study of 2 and 3 factorial experiments in randomized blocks; Complete and partialconfounding. Fractional replication for symmetric factorials. Split plot and split block experiments.

Application areas: Response surface experiments; first order designs and orthogonal designs;

Model validation and use of transformation; Tukey's test for additivity.

REFERENCES

Aloke Dey (1986): Theory of Block Designs, Wiley Eastern.

Angela Dean and Daniel Voss (1999): Design and Analysis of Experiments, Springer.

Das, M.N. and Giri, N.(1979): Design and Analysis of Experiments, Wiley Eastern

Giri,N.(1986): Analysis of Variance, South Asian Publishers

John, RW.M.(1971): Statistical Design and Analysis of Experiments, Macmillan

Joshi,D.D.(1987): Linear Estimation and Design of Experiments, Wiley Eastern

Montgomery,C.D.(1976): Design and Analysis of Experiments, Wiley, New York

Myers, R.H..(1971): Response Surface Methodology, Allyn & Bacon

Pearce,S.C.(1984): Design of Experiments, Wiley, New York

Rao,C.R..and Kleffe, J.(1988): Estimation of Variance Components and applications, North

Holland.

Searle, S. R.. Casella, G. and McCulloch, C. E.. (1992): Variance Components, Wiley.

**ST5A- 605 OPERATIONS RESEARCH I**

Definition and scope of Operational research; phases in Operations Research; models and their solutions. (4 L)

Linear programming problems. Simplex, revised simplex and dual simplex methods, .duality theorem, Post optimality problems and sensitivity analysis transportation and assignment problems;. (15 L)

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. S-s policy for inventory. (12 L )

Queueing models-specifications and effectiveness measures. Steady-state solutions of M/M/1 and M/M/c models with associated distributions of queue-length and waiting time. M/G/1 queue and Pollackzek Khinchine result. Steady-state solutions of M/Ek/l and Ek/M/1 queues. Machine interference problem. (12 L)

REFERENCE:

Taha H.A. (1982) Operational Research: An Introduction; Macmillan.

Gupta P K., D S. Hira: Operations Research: Sultan Chand & Co

Kanti Swarup, Gupta,P.K. and Singh,M.M.. :(1985) Operations Research; Sultan Chand & Sons. Gass, S.I. Linear Programming

Additional REFERENCES

Philips D.T., Ravindran A. and Solberg J.( ) Operations Research, Principles and Practice. Churchman, C. W., Ackoff, R.L., and Arnoff, E.L.(1957) Introduction to Operations Research; John Wiley

Hadley, G. Linear Programming

Sasieni,M,, Yaspan,A, and Friedman,L: Operations Research- Methods and Problems , Wiley

International

Gross, D. aid Harris, C.M.,(1974) Fundamentals of Queuing Theory; John Wiley

Kleinrock L. (1 975) Queueing Systems, vol. 1, Theory; John Wiley

Saaty T.L. (1961) Elements of Queueing Theory with Applications; McGraw Hill

Hadley G. and Whitin T.M. (1963) Analysis of Inventory Systems; Prentice HallStarr M.K. and Miller D.W. (1962) Inventory Control-Theory and Practice; Prentice Hall

Murthy K.G. (1976) Linear and Combinatorial Programming; John Wiley

**ST5A – 607 STATISTICAL PROCESS AND QUALITY CONTROL**

Basic concept of process monitoring and control, process capability and process optimization.(4 L) General theory and review of control charts for attribute and variable data; O.C. and A.R.L. of control

charts; control by gauging; Moving average and exponentially weighted moving average charts; Cusum charts using V-masks and decision intervals; economic design of X-bar chart. (10 L)

Acceptance: sampling plans for attribute inspection; single, double and sequential sampling plans and their properties; plans for inspection by variables for one-sided and two-sided specifications; Mil Std and IS plans; Continuous sampling plans of Dodge type and Wald-Wolfiwitz type and their properties. Bayesian sampling plans.(12 L)

Capability indictor Cp, Cpk and Cpm; estimation confidence intervals and tests of hypotheses relating to capability indices for Normally distributed characteristics. (4 L).

Use of Design of Experiments in SPC; factorial experiments, fractional factorial designs, construction of such designs and analysis of data. (10 L)

Multivariate quality control; use of control ellipsoid and of utility functions. (4 L)

REFERENCES

Montgomery, D C (1985) Introduction to Statistical Quality Control; Wiley Montgomery, D C (1985) Design and Analysis of Experiments; Wiley

Ott, E.R. (1975) Process Quality Control; McGraw Hill**.**

**ST5A - 602 Linear Models And Regression Analysis**

Gauss Markov set-up, Normal equation and least squares estimates, Error and estimation spaces, Variances and co-variances of least squares estimates, estimation of error variances, estimation with correlated observations, least squares estimates with restriction on parameters, simultaneous estimates of linear parametric functions. (15 L)

Test of hypothesis of for one and more than one linear parametric functions, confidence intervals and regions, ANOVA, Power of F-test, multiple comparison tests due to Tukey and Scheffe, simultaneous confidence intervals. (8 L)

Introduction to one –way random effects linear models and estimation of variance components. (4 L Residuals and their plots as tests for departure from assumptions such as fitness of the model normality, homogeneity of variances of outliers. Remedies. (8 L)

Introduction to nonlinear models. (3 L

Multicollineariy, Ridge regression and principal component regression, subset selection of explanatory variables, Mallow’s Cp statistic .(12 L)

REFERENCES

Kshirsagar, A. A course in Linear Models, Marcell Dcker

Cooke, R.D. and Weisberg, S. (1982). Residual and Influence in Regression, Chapman and Hall. Draper, N.R. and Smith, H. (1998). Applied Regression Analysis. 3rd Ed. Wiley.

Gurist, R.F. and Mason, R.L. (1980). Regression Analysis and Its Applications –A Data Oriented

Approach. Marcel and Dekker.Rao, C.R. (1973). Linear Statistical Inference and Its Applications. Wiley Eastern. Weisberg, S.(1985). Applied Linear Regression. Wiley.

**Practicals**: Test of hypothesis of for one and more than one linear parametric functions, confidenceintervals and regions, ANOVA, Power of F-test, multiple comparison tests due to Tukey and Scheffe, simultaneous confidence intervals. Residuals and their plots as tests for departure from assumptions such as fitness of the model normality, homogeneity of variances of outliers.

**ST5A -604 ECONOMETRICS**

Nature of econometrics. The general linear model (GLM) and its extensions. Ordinary least squares (OLS) estimation and prediction. Use of dummy variables and seasonal adjustment. Generalized least squares (GLS) estimation and prediction. Heteroscedastic disturbances. Pure and mixed estimation.

Grouping of observations and of equations. (12 L)

Auto correlation, its consequences and tests, Theil BLUS procedure. Estimation and prediction.

Multicollinearity problem, its implications and tools for handling the problem. Ridge regression. (8 L)

Linear regression with stochastic regressors. Instrumental variable estimation. Errors in variables.

Autoregressive linear regression. Distributed lag models. Use of principal components, canonical

correlations and discriminant analyses in econometrics. (8 L)

Simultaneous linear equations model. Examples. Identification problem. Restrictions on variances and covariances.(8 L)

Estimation in simultaneous equations model. Recursive systems. 2 SLS Estimators. Limited information estimators, k-class estimators. 3 SLS estimation. Full information maximum likelihood method. Prediction and simultaneous confidence intervals. Monte Cario studies and simulation.(12 L)

REFERENCES

Apte PG (1990) : Text book of Econometrics. Tata McGraw Hill.

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

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

Intrulligator, MD (1980) : Econometric models – Techniques and applications, Prentice Hall of India.

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

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

Srivastava, V.K. and-Giles D.A.E. (1987) : Seemingly unrelated regression equations models, Marcel Dekker.

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

Walters, A (1970): An introduction to Econometrics, McMillan & Co.

Wetjeroll,G.B. (1986) : Regression analysis with applications, Chapman Hall.

**ST5A- 606 OPERATIONS RESEARCH II**

Mutti-stage decision processes and Dynamic Programming. Bellman's principle of optimality, general formulation, computational methods and application of dynamic programming. (6)

Integer programming-branch and bound algorithm and cutting plane algorithm. Branch and bound method for solving travelling salesman problem. Multi-criterion and goal programming. (6)

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 2x2, 2xm and mxn games (10)

Non- linear programming-Kuhn Tucker conditions, Wolfe's and Beale's algorithms for solving quadratic programming problems.(6)

Replacement problems; block and age replacement policies; dynamic programming approach for maintenance problems; replacement of items with long. life. (10)

Project management; PERT and CPM; probability of project completion, PERT-crashing. (8L)

Monte-Carlos techniques.(6)

REFERENCES

Taha H.A. (1982) Operational Research: An Introduction; Macmillan.

Sasieni,M,, Yaspan,A, and Friedman,L: Operations Research- Methods and Problems ,

Wiley International

Kanti Swarup, Gupta,P.K. and Singh,M.M.. (1985) Operations Research; Sultan Chand &

Sons.

Gupta,P.K. and Hira,D.S. Operations Research, S. Chand & Co.

Hadley G. (1 964) Non-linear and Dynamic programming; Addison Wesley

Mckinsey J.C.C. (1952) Introduction to the Theory of Games; McGraw Hi

**ST5A -608 : PLANNING AND ANALYSIS OF INDUSTRIAL EXPERIMENTS**

Analysis of single replicate of 2k Full Factorial Experiment total and artial confounding in 2k full Factorial m E>periment, Resolution III, IV and V fractions of 2k experiments. (10 L)

Criteria in selecting factorial designs: Criteria based on the Spectrum of the information matrix-A and D optimality Criteria based on alias matrix. (8 L )

Construction of layouts of orthogonal array experiments and associated linear graphs to study some of the main effects and first order interactions of 2^K designs which need not be resolution 3 designs, (designs known as Taguchi designs) with special cases of L\_8 and L\_16. (12 L)

3^K Full factorial designs, Total and confounding in 3^ K Factorial experiments. Construction of Orthogonal array experiments involving three level factors, with special cases of L\_9, and L\_18. (12 L) Roll of Center Composite Designs (CCD) as alternative to 3k designs, probability of CCD, Linear and quadratic Response surfaces, contour plots. (8 L)

Role of non normality, Box-Cox transformation, Generalized linear models (GLIM), for exponential family of distributions.(8 L)

REFERENCES

D. C. Montgomery: Design and Analysis of Experiments, J. Wiley and Sons (Asia) 5th edition (2001). R.H. Myers & D. C. Montgomery: Response Surface Methodology, J, Wiley and Sons.

J. Fox : Quality through Design, McGraw-Hill Book Company, 1993. J.A. Nelder and P. McCullagh : Generalized Linear Models, 2nd edition.

B. L. Raktoe, A. Hedayat and W.T. Federer, Factorial Designs, J, Wiley and Sons. 1981.

**ST5A -610 Real Analysis:**

Elementary set theory, finite, countable and uncountable sets, Real number system as a complete ordered field, Archimedean property, supremum, infimum. Sequences and series, convergence, limsup, liminf.

Bolzano Weierstrass theorem, Heine Borel theorem. Continuity, uniform continuity, differentiability, mean value theorem. Sequences and series of functions, uniform convergence, Riemann sums and Riemann integral, Improper Integrals. Monotonic functions, types of discontinuity, functions of bounded variation, Lebesgue measure, Lebesgue integral. Functions of several variables, directional derivative, partial derivative, derivative as a linear transformation, inverse and implicit function theorems.

Metric spaces, compactness, connectedness. Normed linear Spaces. Spaces of continuous functions as examples.

Reference:

Walter Rudin, Principles of Mathematical Analysis(3rd edition), McGraw-Hill international editions

T.M. Apostol, Mathematical Analysis(2nd edition), Narosa Publishing House, New Delhi, H.L. Royden, Real Analysis(4th edition), Macmillan Publishing Company

**Syllabus**

**Ph.D. Course work**

**Study centre : School of Statistics**

Plan of Examination

The course work will be of 16 credits

|  |  |  |  |
| --- | --- | --- | --- |
| S.No. | Nomenclature | Code | Credits |
| 1. | Research  Methodology | Stat\_PhD\_1 | 4 |
| 2. | Review of Published  Research in the relevant field | Stat\_PhD \_2 | 3 |
| 3. | Computer  Applications | Stat\_PhD\_3 | 3 |
| 4. | Advance course in the relevant subject | Stat\_PhD\_4 | 3 |
| 5. | Comprehensive Viva - Voce | Stat\_PhD\_5 | 3 |

The requirement of pass marks, attendance and other examination related matters will be as per ordinance 18 of DAVV.

**Paper I**

# STAT\_PhD\_1

**Research methodology (4 credits)**

**Unit I:**

Research Methodology (Number of Lectures=15)

1) Meaning of Research Methodology; Difference (s) between Methods of Research & Research Methodology; Motivation for Research, Research approaches and Related Tools, Conditions and criteria for good research.

2) Choosing the research area, Factors leading to the choice, Defining the concrete research problem and focusing on it.

3) Importance of communication skill in research-Development of power of expression in both speaking and writing, Good presentation techniques. Progress report writing on the research topic (s).

4) Objectivity, Reality and Ethics in research the Dilemmas and the Decision –Makings vis-à-vis the Reality.

**Unit II:**

Research Methodology in Mathematics

Research tools, Searching Google, MathSciNet, Scopus impact factor, h-index, Google Scholar, ORCID, JStor, Online and open access journals, virtual

Library if various countries

Scientific writing and presentation writing a research paper, Survey article, thesis writing;

**Unit III: Probability Theory:** Overview of some important results in commonly used distributions and their properties:

**Unit I V** Overview of the following families of distribution and their properties: Exponential family, Pitaman Family, Pearson Family.

**References:**

An Outline of statistical theory Vol I and Vol II: Goon, A.M., Gupta, MK Dasgupta, B. world Press .

A first course on Parametric Inference: Kale, B.K. , Narasa Publisher .

**Paper II STAT\_PhD\_ 2**

**Review of Published Research in the relevant field (3 Credits)**

Review of published literature in the relevant field

Review of topics related to area of research using internet, hard copies of papers, w ebsites, cross referencing etc.

**Paper II I STAT\_PhD\_ 3**

**Computer Applications (3 Credits)**

**Unit I:** C programming for exploratory statistical analysis and optimization techniques. (12 L)

**Unit II:** Use of MS Excel and/ or SPSS for descriptive and analytical stati stical (10 L)

**Unit III:**

Use of ICT: Presentation of research work though PPT (5 L) Introduction to R programming/ Matlab/ Mathematical/ Minitab (6 L) **References:**

Let us C Kanetkar, Y.P. BPB Publications

The C Programming Language: Brian W, Kernighan Dennis Ritchie, Prentice Hall

Computer Programming in C: V. Rajaraman, PH

**Paper I V**

# STAT\_PhD\_ IV

**Advance course in the relevant subject**

**Unit I : Overview of result s in** Gauss - Markov models, estimability of parameters, best linear unbiased estimators.

**Unit II: Over view of results in Optimization Techniques:** Introduction, classification of optimization problems, Linear Programming. Diffevent optimality Criterion using information matrix (C) of Block designs i.e. A, D and

E optimal designs. Efficiency and Vaviance Bal anced Block designs.

**Unit III:** Classical optimization techniques: single variable optimization, multivariable optimization with no constraints, constrained optimization,.

**Unit IV: Overview of Results in Nonlinear opt imization techniques.** Unconstrained and constrained optimization techniques: Gradient method, Kuhn - Tucker conditions, sensitivity analysis (ll L)

**References:**

Modern Mathematical Statistics: Dudewicz E.J. and Mishra S.N. (Wiley Series in Probability and Statistics)

**An Introduction to Probabilit y and Stat istics: Rohat gi, V.K. and Ehsanes Saleh, A.K. MD., John Wiley & Sons,.**

A course in linear Models: Kshirsagar, A.M., M. Dekker

Optimization Theory and Applications: S.S. Rao, Wiley Eastern

Nonlinear Programming Theory and Algorithms: Bazaraa, M.S. and Shetty,

C.M. and Shetty, John Wiley Sons

Operation Research: Gupta PK, DS Hira, Sultan Chand & Co

Operation Research: Kanti Swaroop, P.K. Gupta & Manmohan, Sultan Chand & Co..

Theory of Block Designs: Aloke Dey, Wiley Eastem Limited.