

ST.101: REAL ANALYSIS

Elements of Set Theory, Sets in Euclidian space of k -dimension (R_k), rectangles, neighbourhood, interior point and limit point, open and closed sets, Bolzano-Weierstrass theorem in R_2 . Real valued functions-Continuity and Uniform Continuity.

Sequences and Series of constants- Limit superior, limit inferior and limit-properties. Cesaro sequences. Series of positive terms - Tests for convergence/divergence. Integral and Order tests and Kummers test(statement only of all the tests)-Ratio and Rabe's tests as special cases of Kummers test. Series of arbitrary terms.-absolute and conditional convergence.

Sequences of functions-Uniform convergence and point wise convergence, Series of functions-uniform convergence-Weierstrass M test. Power series and radius of convergence. Riemann-Stieltjes integration-continuous integrand and monotonic/differentiable integrater.

Functions of two variables-partial and directional derivatives. Maxima and minima of functions, maxima-minima under constraints(Lagrange's multipliers). -parametric functions. Uniform convergence of improper integrals, Differentiation under integrals. Double integrals and repeated integrals. change of variables. under double integration-statement of the theorems without proof and solution of problems.

REFERENCES

1. Apostol, T.M.(1985): Mathematical Analysis, Narosa India Ltd.
2. Courant R and John F (1965): Introduction to Calculus and Analysis, Wiley
3. Goldberg R.R.(1970): Methods of Real Analysis, Oxford Publishing Co.
- 4 Rudin W (1976): Principles of Mathematical Analysis, Mc Grow hill
- 5 Shanthinarayan (1950) : A course on Mathematical Analysis, S.Chad and Co.

ST. 102: LINEAR ALGEBRA

Fields, vector spaces, 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. (6 L)

Vector spaces with an inner product, Gram-Schmidt orthogonalization process. Orthonormal basis and orthogonal projection of a vector. . (4 L)

Linear 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. (6 L)

Hermite canonical form, generalized inverse, Moore-Penrose inverse, idempotent matrices. Solutions of matrix equations. (5 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 characteristic roots, spectral decomposition of a real symmetric matrix, reduction of a pair of real symmetric matrices, Hermitian matrices. (12 L)

Singular values and singular decomposition, Jordan decomposition, extrema of quadratic forms. Vector and matrix differentiation. (6 L)

Total: (45 L), (15 T)

REFERENCES

1. Bellman, R. (1970): Introduction to Matrix Analysis, 2nd Ed., McGraw Hill.
2. Biswas, S. (1984): Topics in Algebra of Matrices, Academic Publications.
3. Graybill, F. A. (1983): Matrices with Applications in Statistics, 2nd Ed., Wadsworth.
4. Hadley, G. (1987): Linear algebra, Narosa.
5. Halmos, P. R. (1958): Finite Dimensional Vector Spaces, 2nd Ed., D. Van Nostrand Company.
6. Hoffman, K. and Kunze, R. (1971): Linear Algebra, 2nd Ed., Prentice Hall.
7. Rao, A. R. and Bhimasankaram, P. (1992): Linear Algebra, Tata McGraw Hill.
8. Rao, C. R. (1973): Linear Statistical Inference and its Applications, 2nd Ed., Wiley.
9. Rao, C. R. and Mitra, S. K. (1971): Generalized Inverse of Matrices and its Applications, Wiley.
10. Searle, S. R. (1982): Matrix Algebra Useful for Statistics, Wiley.

ST. 103: PROBABILITY THEORY AND DISTRIBUTIONS - I

Classes of sets, sequence of sets, limit superior and limit inferior of a sequence of sets, fields, sigma fields, minimal sigma field, Borel sigma field on the real line. Events, Sample space, Probability measure, Additive property, Properties related to sequences of events, Independent events, Conditional probability and Bayes' theorem.

Measurable functions, random variables, sums, product and functions of random variables, sequence of random variables. Induced Probability measure, Distribution function – Jordan decomposition theorem. Bivariate distributions-joint, marginal and conditional distributions. Expectations and conditional expectations.

Standard discrete and continuous univariate distributions and their properties, Probability generating function and moment generating function. Bivariate normal and multinomial distributions

Transformation technique. Sampling distributions, Chi-square, t , F and Non-central chi-square and their properties. Bivariate Negative Binomial, Beta and Gamma distributions.

Markov, Chebyshev, Hoelder, Minkowski, Jensen and Liapunov inequalities . Relationship between tail of distributions and moments.

REFERENCES

1. Cramer, H. (1946): Mathematical Methods of Statistics, Princeton.
2. Johnson, S. and Kotz, (1972): Distributions in Statistics, Vols.I, II and III, Houghton and Mifflin.
3. Mukhopadhyaya, P. (1996): Mathematical Statistics, Calcutta Publishing House.
4. Pitman, J. (1993): Probability, Narosa.
5. Rao, C. R. (1973): Linear Statistical Inference and its Applications, 2nd Ed., Wiley Eastern.
6. Rohatgi, V. K. (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
7. Lukacs C (1970) : Characteristic functions, Griffin Publications

ST. 104: STATISTICAL COMPUTING

Programming in 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 with a more advanced unit in object oriented programming in C++ or Java. Topics should include simple syntax, loops, pointers and arrays, functions, input/output, and linking to databases.) (18L, 8P)

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, matrix computations, drawing random samples from known univariate probability distributions -both discrete and continuous) (12L, 8P)

Analysis of interesting data sets using known techniques on a suitable statistical package such as MINITAB, SAS, SPSS or JMP IN: Topics should include graphics, descriptive statistics, representation of multivariate data, hypotheses testing, analysis of variance and linear regression. (0L, 19P)

Total: (30L),(35P)

REFERENCES

1. Kerningham, B. W. and Ritchie, D. M. (1988): The C Programming Language, 2nd Ed., Prentice Hall.

2. Press, W. H., Teukolsky, S. A., Vetterling, W. T. and Flannery, B. P. (1993): Numerical recipes in C, 2nd Ed., Cambridge University Press.
3. Ryan, B. and Joiner, B. L. (2001): MINITAB Handbook, 4th Ed., Duxbury.
4. Thisted, R. A. (1988): Elements of Statistical Computing. Chapman and Hall.

ST. 201: PROBABILITY THEORY AND DISTRIBUTIONS – II

Lebesgue and Lebesgue Stieltjes measure on the real line. Integration of measurable functions with respect to measures. Monotone convergence theorem, Fatou's lemma and dominated convergence theorem.

Convergence in distribution, in Probability and with probability 1 and their implications. Slutsky's theorem. Weak law of large numbers- Kolmogorov's generalized WLLN (proof of sufficient condition only), Khintchen's WLLN as special case, Chebychev's Weak law.

Borel-Cantelli lemma, Kolmogorov's inequality. Strong law of large numbers - Kolmogorov's SLLN's for independent sequences and deduction for the i.i.d. case. Definitions and examples of Markov dependent, exchangeable and Stationary sequences.

Characteristic function - properties, Inversion theorem (statement only and proof for density version), Uniqueness theorem, Continuity theorem (statement only). Central limit theorem- Lindberg-Feller form (statement only). Deductions of Levy-Lindberg and Liapunov's forms.

Order Statistics- their distributions and properties, Joint and marginal distributions. Extreme value distributions and their properties. Extreme value distributions as limit laws for the case of exponential, Normal, Uniform and Pereto .

REFERENCES

6. Cramer, H. (1946): Mathematical Methods of Statistics, Princeton.
7. Johnson, S. and Kotz, (1972): Distributions in Statistics, Vols.I, II and III, Houghton and Mifflin.
8. Mukhopadhyaya, P. (1996): Mathematical Statistics, Calcutta Publishing House.
9. Pitman, J. (1993): Probability, Narosa.
10. Rao, C. R. (1973): Linear Statistical Inference and its Applications, 2nd Ed., Wiley Eastern.
- 6 Rohatgi, V. K. (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
7. Lukacs C (1970) : Characteristic functions, Griffin Publications

ST.202: SAMPLE SURVEYS AND STATISTICS FOR NATIONAL DEVELOPMENT

A. SAMPLE SURVEYS

Basic finite population sampling techniques (srs wr/wor, stratified, systematic), related problems of population mean estimation, allocation problems in stratified sampling. (5 L)

Unequal probability sampling: pps wr/wor methods (including Lahiri's scheme) and related estimators of a finite population mean (Hansen-Hurvitz and Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2) (8 L)

Ratio and regression estimators based on srs wor method of sampling, two-stage sampling with equal number of second stage units, double sampling, cluster sampling. (12 L)

Total: (25 L), (10 P)

B. STATISTICS FOR NATIONAL DEVELOPMENT

Economic development; growth in per capita income distributive justice. Indices of development, Human Development Index. (4 L)

Estimation of National Income – product approach, income approach and expenditure approach. Population growth in developing and developed countries. Population projection using Leslie matrix. Labour force projection. (8 L)

Measuring inequality of incomes, Gini coefficient, Theil's measure. Poverty measurement- different issues, measures of incidence and intensity, combined measures, eg. Indices due to Kakwani, Sen.etc. (8 L)

Total: (20 L), (2 T), (3 P)

REFERENCES

1. Choudhary, A. and Mukherjee, R. (1989): Randomized Response Techniques, Marcel Decker
2. Cochran, W. G. (1977): Sampling techniques, 3rd Ed., Wiley
3. Des Raj and Chandak (1998): Sampling Theory, Narosa.
4. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
5. Singh, D. and Choudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, New Age International.
6. Sukhatme et al. (1984): Sampling Theory of Surveys with Applications, Iowa State University Press and IARS.
7. C.S.O. (1980): National Accounts Statistics- Sources and Health.
8. Keyfitz, N. Mathematical Demography
9. UNESCO : Principles Vital Statistics Systems, Series M-12.
10. Sen, A.(1997): Poverty and Inequality.

ST. 203: INFERENCE –I

Parametric models; point estimators; tests of hypotheses; interval estimation viewed as decision problems with given loss functions. Joint distribution of the sample and a statistic. Likelihood function: examples from standard discrete and continuous models. Plotting likelihood functions for these models up to two parameters. (6 L)

Information in data about the parameters as variation in likelihood function; concept of no information; sufficiency; Neyman factorizability criterion; checking sufficiency; likelihood equivalence. Minimal sufficient statistic; exponential families; Pitman families. Invariance property of sufficiency under one-one transformation of sample space and parameter space. Fisher information for one and several parameter models. Fisher's theorem about loss of information – Fisher's theorem in matrix form without proof. (7 L)

Methods of estimation : method of moments; percentiles; and maximum likelihood. Choice of estimators based on unbiasedness, minimum variance and mean squared error; minimum variance unbiased estimators, Rao-Blackwell theorem, completeness, Lehmann-Scheffe theorem; necessary and sufficient conditions for MVUE, Cramer-Rao lower bound approach. (11 L)

Tests of hypotheses, critical regions, test functions; two kinds of errors, size function, power function, level of significance. UMP test in class of size α tests, Neyman-Pearson lemma. UMP test for simple null against one sided alternatives and UMP test 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 distributions with MLR property; non-existence of UMP test for simple null against two sided alternatives in one parameter exponential family. Introduction to standard one sample and two sample nonparametric test for location. (17 L)

Interval estimation: confidence level, construction of confidence intervals using pivots, shortest expected length confidence interval, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses; nonparametric confidence intervals for percentiles. (4 L)

Total: (45 L), (15 T)

REFERENCES

1. Ferguson, T. S. (1967): *Mathematical Statistics*, Academic Press.
2. Kale, B. K. (1999): *A First Course on Parametric Inference*, Narosa.
3. Lehmann, E. L. (1986): *Theory of Point Estimation*, Wiley.
4. Lehmann, E. L. (1986): *Testing Statistical Hypotheses*, Wiley.
5. Mukhopadhyaya, P. (1998): *Mathematical Statistics*, New Central Book Agency, Calcutta.
6. Rao, C. R. (1973): *Linear Statistical Inference*, Wiley Eastern.
7. Rohatgi, V. (1988): *An Introduction to Probability and Mathematical Statistics*, Wiley Eastern.

ST. 204: LINEAR MODELS AND REGRESSION ANALYSIS

Gauss-Markov setup, normal equations and least squares estimates, error and estimation space, variance and covariance of least squares estimates, estimation of error variance, estimation with correlated observations, least squares estimates with restriction on parameters, simultaneous estimates of linear parametric functions. (12 L)

Test of hypothesis for one and more than one parametric functions. Confidence intervals and regions, analysis of variance table, power of F-test, multiple comparison test like Tukey and Scheffe, simultaneous confidence interval. (9 L)

One way linear models when parameters are random and estimation of variance components. Simple linear regression, multiple regression, fit of polynomials and use of orthogonal polynomial. Introduction to non-linear models, residuals and their plot for examining the departure from assumptions such as fitness of the model, normality, homogeneity of variances and detection of outliers and remedies. (18 L)

Multicollinearity, ridge and principal component regression, subset selection of explanatory variables and Mallows's C_p statistic. (6 L)

Total: (45 L), (20 P)

REFERENCES

8. Cook, R.D. and Weisberg, S. (1982): *Residual and Influence in Regression*. Chapman and Hall, London.
9. Draper, N.R. and Smith, H. (1998): *Applied Regression Analysis*. 3rd Ed. Wiley, New York.
10. Gunst, R.F. and Mason, R.L. (1980) : *Regression Analysis and its Application – A Data Oriented Approach*, Marcel-Dekker.
11. Rao, C. R. (1973): *Linear Statistical Inference*, Wiley Eastern.
12. Weisberg, S. (1985): *Applied Linear Regression*, Wiley.

ST. 302: INFERENCE – II

Review of convergence in probability and convergence in distribution. Cramer theorems. Slutsky's theorem. (4 L)

Consistent estimation of real and vector valued parameter. Invariance of consistent estimator under continuous transformation, consistency of estimators by the method of moments and by the method of percentiles. Mean squared error criterion, asymptotic relative efficiency, error probabilities and their rates of convergence, minimum sample size required to attain given level of accuracy. (8 L)

Consistent Asymptotic Normal (CAN) estimator, invariance of CAN estimator under differentiable transformation, CAN property of estimators obtained by moments and percentiles, CAN estimators obtained by the method moments in one parameter exponential family, extension to multi parameter exponential family, examples of consistent but not asymptotically normal estimators from Pitman family. (6 L)

Method of maximum likelihood, CAN estimators for one parameter exponential and Cramer families, Cramer-Huzurbazaar theorem, solution of likelihood equations, method of scoring, Newton-Raphson process and other iterative procedures, Fisher lower bound to asymptotic variance, extension to multi parameter case without proof, multinomial distribution with cell probabilities depending on a parameter. (8 L)

MLE in Pitman family and double exponential distribution, MLE in censored and truncated distributions. (4 L)

Likelihood Ratio Test (LRT), asymptotic distribution of LRT statistic, Wald's test, Rao's score test, Pearson's chi-square test for goodness of fit, Bartlett's test. Large sample tests and confidence intervals based on CAN estimators, variance stabilizing transformations and large sample tests, consistency of large sample tests, asymptotic power of large sample tests. (15 L)

Total: (45 L), (15 T)

REFERENCES

13. Ferguson, T. S. (1996): A Course on Large Sample Theory, Chapman and Hall.
14. Kale, B. K. (1999): A First Course on Parametric Inference, Narosa.
15. Lehmann, E. L. (1986): Testing Statistical Hypotheses, Wiley.
16. Mukhopadhyaya, P. (1998): Mathematical Statistics, New Central Book Agency, Calcutta.
17. Rao, C. R. (1973): Linear Statistical Inference, Wiley Eastern.
18. Rohatgi, V. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern.

ST. 303: 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) of 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; Missing plot technique - general theory and applications.

General factorial experiments, factorial effects; best estimates and testing the significance of factorial effects; study of 2^M and 3^M factorial experiments in randomized blocks; Complete and partial confounding. Fractional replication for symmetric factorials. Response surface experiments

REFERENCES

1. Alope Dey (1986): Theory of Block Designs, Wiley Eastern
2. Angela Dean and Daniel Voss (1999): Design and Analysis of Experiments, Springer
3. Das, M.N. and Giri, N.(1979): Design and Analysis of Experiments, Wiley Eastern
4. Giri,N.(1986): Analysis of Variance, South Asian Publishers
5. John, P.W.M.(1971): Statistical Design and Analysis of Experiments, Macmillan
6. Joshi,D.D.(1987): Linear Estimation and Design of Experiments, Wiley Eastern
7. Montgomery,C.D.(1976): Design and Analysis of Experiments, Wiley, New York
8. Myers, R.H.(1971): Response Surface Methodology, Allyn & Bacon
9. Pearce,S.C.(1984): Design of Experiments, Wiley, New York
- 10.Rao,C.R..and Kleffe, J.(1988): Estimation of Variance Components and Applications
North Holland.
- 11.Searle, S. R., Casella, G. and McCullugh, C. E.. (1992): Variance Components,
Wiley

ST. 304: MULTIVARIATE ANALYSIS

Random sampling from multivariate normal distribution, maximum likelihood estimators of parameters, distribution of sample mean vector. (3 L)

Wishart distribution (statement only) and its properties; distribution of sample generalized variance. Null distributions of sample correlation coefficient, partial and multiple correlation coefficients, distribution of sample regression coefficients. Application in testing and interval estimation. (10 L)

Hotellings. – T^2 . Null distribution of Hotelling's T^2 statistic, Application in test on mean vectors for single and several multivariate normal populations. (6 L)

Multivariate linear regression model, estimation of parameters, testing linear hypothesis about regression coefficients. Likelihood ratio test criterion. Multivariate analysis of variance of one and two way classified data. (10 L)

Classification and discrimination procedures for discrimination into one of two multivariate normal populations. Sample discriminant function, tests associated with discriminant function, probabilities of misclassification and their estimation, classification into more than two multivariate normal populations. (8 L)

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

Total: (45 L), (15 P)

REFERENCES

19. Anderson, T.W. (1983): An Introduction to Multivariate Statistical Analysis, 2nd ed., Wiley.
20. Giri, N.C. (1977): Multivariate Statistical Inference, Academic Press.
21. Johnson and Wichern (1986) : Applied Multivariate Analysis, Wiley.
22. Kshirsagar, A.M. (1972): Multivariate Analysis, Marcel-Dekker.
23. Morrison, D.F. (1976): Multivariate Statistical Methods, 2nd ed., McGraw Hill.
24. Muirhead, R.J. (1982) : Aspects of Multivariate Statistical Theory. Wiley.
25. Rao, C.R. (1973). Linear Statistical Inference and its Applications. 2nd ed., Wiley Eastern.
26. Seber, G.A.F. (1984) : Multivariate Observations. Wiley.
27. Sharma, S. (1996). Applied Multivariate Techniques. Wiley.
28. Srivastava, M.S. and Khattree, C.G (1979). An Introduction to Multivariate Statistics North Holland.

ST. 401: PROBABILITY MEASURES ON METRIC SPACES

Probability measures on metric spaces: Measures and integrals, tightness, (measure) determining class. Weak convergence of measures: properties of weak convergence and Portmanteau theorem: Convergence determining class. (10 L)

Some special cases: Convergence of probability measures and convergence determining class in the Euclidean space, the circle, the space R^n , the product spaces etc. (5 L)

Random element of a metric space and its distribution, convergence in distribution of a sequence of random elements – various equivalent criteria for convergence; convergence in probability; weak convergence and mappings. (10 L)

Relative compactness and Prohorov's theorem. Weak convergence and tightness in $C[0,1]$; Wiener measure. Weak convergence and tightness in $D[0,1]$; Donsker's theorem. (20 L)

Total: (45 L), (15 T)

REFERENCES

1. Billingsley, P. (1968): Convergence of Probability Measures, Wiley.
2. Parthasarathy, K. R. (1967): Probability Measures on Metric Spaces, Academic Press.

ST.402: NONPARAMETRIC AND SEMIPARAMETRIC METHODS

Empirical distribution function, Glivenko-Cantelli theorem, Kolmogorov goodness of fit test.

One sample U-statistics, Kernel and symmetric kernel, two sample U-statistics, asymptotic distribution of U-statistics. UMVUE property of U-statistics, asymptotic distribution of linear function of order statistics.

Rank tests, locally most powerful rank test, linear rank statistics and their distributional properties under null hypothesis, Pitman's asymptotic relative efficiency.

One sample location problem, sign test and signed rank test, two sample Kolmogorov Smirnov tests. Two sample location and scale problems. Wilcoxon-Mann-Whitney test, normal score test, ARE of various test based on linear rank statistics. Kruskal-Wallis K sample test.

Cox's proportional hazards model, rank test (partial likelihood) for regression coefficients, concepts of jackknifing method of Quenouille for reducing bias, bootstrap methods, confidence intervals.

REFERENCES

1. Cox, D.R. and Oakes, D. (1983). *Survival Analysis*, Chapman and Hall.
2. Davison, A.C. and Hinkley, D.V. (1997). *Bootstrap methods and their application*, Cambridge University Press.
3. Fraser, D.A.S. (1957). *Nonparametric methods in Statistics*, John Wiley.
4. Gibbons, J.D. (1985). *Nonparametric Statistical Inference*. 2nd Ed., Marcel-Dekker.
5. Hajek, J. and Sidak, Z. (1967). *Theory of Rank Tests*. Academic Press.
6. Puri, M.L. and Sen, P.K. (1971). *Nonparametric methods in multivariate analysis*. Wiley.
7. Randles, R.H. and Wolfe, D.A. (1979). *Introduction to the theory of nonparametric statistics*. Wiley.

ST.403: OPERATIONS RESEARCH

Definition and scope of Operational research; phases in Operational research; models and their solutions; decision-making under uncertainty and risk, use of different criteria; sensitivity analysis. (2 L)

LP Problem – Simplex method, Karmarkar's algorithm, duality theorem; transportation and assignment problems; Wolfe's and Beale's algorithms for solving quadratic programming problems. Dynamic programming, Bellman's principle of optimality, general formulation, computational methods and applications of dynamic programming.

(16 L)

Analytical structure of inventory problems; EOQ formula of Harris and 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 ((t S)policy).

(10 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. Queues with truncation Machine interference problem. M/G/1 queue and Pollaczek-Khinchine result. Stady – state solution of M/Ek/1.

(10 L)

PERT and CPM; Probability of project completion; PERT – crashing.

(5 L)

Total: (45 L), (15 T/P)

REFERENCES

1. Churchman, C.W., Ackoff, R.L. and Arnoff, E.L. (1957). Introduction to Operations Research.
2. Hillier, F.S. and Leiberman, G.J. (1962). Introduction to Operations Research.
3. Kanti Swarup and Gupta, M.M. (1985).; Operations Research.
4. Philips, D.T., Ravindran, A. and Solberg, J. Operations Research, Principles and Practice.
5. Taha, H.A. (1982). Operational Research.

ST.404: STATISTICAL PROCESS CONTROL AND TOTAL QUALITY MANAGEMENT

Concept of quality. Quality characteristics. Control charts for variables and attributes. OC and ARL of control charts. Moving average (MA) and EWMA and CUSUM Charts. Process control with auto correlated observations. Multivariate control charts.

Capability indices Cp, Cpk, and Cpm; estimation, confidence intervals and test of hypotheses.

Acceptance sampling plans for attribute inspection Single, Double, Multiple and Sequential sampling plans and their properties; Plans for inspection by variable for one-sided and two-sided specifications; continuous sampling plans – chain sampling plans TQM.

TQM the seven QC tools. Quality costs. Six-sigma programme. Quality systems – ISO 9000 standards series. Quality circles.

REFERENCES

1. Johnson, N.L. and Kotz, S (1993): Process capability indices, Chapman and Hall
2. Montgomery, D. C. (1985): Statistical Process Control. Wiley,
3. Shridhara Bhat K. (2002): Total Quality Management Himalaya Publishing House.

ST. 405: RELIABILITY ANALYSIS

Life distributions : reliability function; hazard rate; common life distributions – exponential, Weibull, Gamma, etc. Estimation of parameters and test in these models.

Notions of ageing : IFR, IFRA, NBU, DMRL, and NBUE classes and their duals; loss of memory property of the exponential distribution; closures of these classes under formation of coherent systems, convolutions and mixtures.

Univariate shock models and life distributions arising out of them; bivariate shock models; common bivariate exponential distributions and their properties.

Reliability estimation based on failure times in various censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation.

Maintenance and replacement policies; availability of repairable systems; modelling of a repairable system by a non-homogeneous Poisson process.

Reliability growth models; probability plotting techniques; Hollander-Proschan and Deshpande tests for exponentiality; test for HPP vs. NHPP with repairable systems.

Basic ideas of accelerated life testing.

REFERENCES

6. Barlow, R.E. and Proschan, F. (1985). Statistical Theory of Reliability.
7. Lawless, J.F. (1982). Statistical Models and Methods of Life Time Data.
8. Bain, L.J. and Engelhardt (1991). Statistical Analysis of Reliability and Life Testing Data.
9. Zacks, S. Reliability Theory.

ST. 406: TIME SERIES ANALYSIS

Time series as discrete parameter stochastic process, auto-covariance and auto-correlation functions and their properties. (5 L)

Detailed study of the stationary processes : (i) moving average (MA), (ii) auto-regressive (AR), (iii) ARMA, and (iv) AR integrated MA (ARIMA) models. Box-Jenkins models.

Discussion (without proof) of estimation of mean, auto-covariance and auto-correlation functions under large sample theory. Choice of AR and MA orders. Estimation of ARIMA model parameters. Forecasting. Residual analysis and diagnostic checking. Use of computer packages like SPSS and TSP. (25 L)

Spectral analysis of weakly stationary process, periodogram and correlogram analyses, computation based on Fourier transform, Spectral decomposition of weakly ΔR process and representation as a one-sided MA process – necessary and sufficient conditions. Implication in prediction problems. State space representation of time series. Kalman filter techniques. (15 L)

Total: (45 L), (15 T/P)

REFERENCES

01. Anderson, T.W. (1971). *The Statistical Analysis of Time Series*. Wiley.
02. Bloomfield, P. (2000). *Fourier Analysis of Time Series : An Introduction*. 2nd ed. Wiley.
03. Box, G.E.P., Jenkins, G.W. and Reinsel, G.C. (1994). *Time Series Analysis : Forecasting and Control*. Prentice Hall.
04. Box, G.E.P. and Jenkins, G.M. (1976). *Time Series Analysis – Forecasting and Control*. Holden-day, San Francisco.
05. Chatfield, C. *Analysis of Time Series – Theory & Practice*. 3rd ed., Chapman & Hall.
06. Chow, C.G. (1985). *Econometrics*. Mc Graw Hill.
07. Findley, D.F. ed., (1981). *Applied Time Series Analysis II*. Academic Press.
08. Fuller, W.A. (1976). *Introduction to Statistical Time Series*. Wiley.
09. Granger, C.W.J. and Newbold (1984). *Forecasting Econometric Time Series*, 3rd ed.. Academic Press.
10. Granger, C.W.J. and Hatanka, M. (1964). *Spectral Analysis of Economic Time Series*, Princeton University Press.
11. Hannan, E.J. (1960). *Time Series Analysis*, Methuen, London.
12. Kendall, M.G. (1974). *Time Series*, Charles Griffin, London.
13. Kendall, M.G. and Stuart, A. (1966). *The Advanced Theory of Statistics*, Vol. 3, Charles Griffin, London.
14. Koopmans, L.H. (1974). *The Spectral Analysis of Time Series*, Academic Press.
15. Montgomery, D.C. & Johnson, L.A. (1977). *Forecasting and Time Series Analysis*, McGraw Hill.
16. Nelson, C.R. (1973). *Applied Time Series for Managerial Forecasting*. Holden-day.
17. Priestly, M.B. (1981). *Spectral Analysis & Time Series*. Griffin, London.

ST.407: BIO-STATISTICS

Definition, agent, host and environment, mode of transmission, incubation period, spectrum of disease, herd immunity, classification of cause of death, measures of mortality, studies of mortality. Measures of morbidity, morbidity surveys, issues and problems. Risk, cause and bias. Observational studies: retrospective, cross sectional and prospective studies.

Clinical trials: Methods of randomization, ethical issues, cross over trials. Sequential and group sequential trials. Interim analysis, multiple testing and stopping rules. Equivalence trials.

Clinical Epidemiology: Definition, reliability, validity, sensitivity, specificity, predictive values, likelihood ratio test, selection and interpretation of diagnostic test. Deciding on the best therapy, ROC curves, multiple and parallel test. Screening for disease, critical appraisal, Meta analysis. Epidemiologic Models - Epidemiometric studies - Deterministic epidemic models: Simple, General, Recurrent.

Time Series (Epidemic or others) Applications of Time series analysis in epidemiology - Simple descriptive techniques for detecting seasonal, Cyclical, secular and random variations

REFERENCE

1. Lilienfeld A.M. & Lilienfeld D.C. Foundations of epidemiology. II Edn. Oxford Univ. Press, New York, 1980
2. Fletcher R.H. Fletcher S.W. and Wagner E.H. Clinical Epidemiology - the essentials. II Edn, 1982.
3. Harold A.Hahn, Christopher t.Sempos. Statistical Methods in Epidemiology, Oxford Univ. Press, New York, 1989.
4. David G.Kleinbaum, Lawrence L.Kupper and Hall Morgenstern. Epidemiologic Research, Van Nostrand, USA, 1982
5. Chatfield C. The Analysis of Time Series - An Introduction. III Edn., Chapman & Hall, London, 1984 (Chapters 1, 2,3,4,5,6,7).
6. Bailey N.T.J.The Mathematical Approach to Biology and Medicine. Chapters 1,2,and 9, John Wiley, 1967.

ST 408: ANALYSIS OF CATEGORICAL DATA

Categorical or count data, contingency table investigations associated with contingency table hypotheses of independence in two-and three-way tables; analysis by fitting marginals log linear representation, internal constraints problem, analysis of information, fitting strategies, algorithms to calculate quadratic approximations, confidence intervals.

Application, general linear hypotheses; external constraints problem; general formulation of MDI analysis, - single and K-sample cases, minimum modified chi-square estimations.

No linear interaction; general formularize in three-way table $2 \times 2 \times 2$ table $4 \times 2 \times 2$ table as examples.

Discrete classification models, full multinomial model and its variations.

Models for multivariate dichotomous responses- Bahadur model, loglinear and logit methods, Martin-Bradley model, Kronmal - Ott - Tarter model, procedure based on distributional distance.

Variable selection problem - based on differences in discriminant score, Raiffa methods, Lachin's procedure, Kullback's divergence statistics procedure, Mixture of variables - Krazanowski's model and its analysis

REFERENCE

1. Gokhale, D.V. and Kullback, S. : The information in contingency table, Marcel Dekker, 1979
2. Goldstein, M. and Dillon, W.R. : Discrete Discriminant Analysis John Wiley, New York 1978

ST.409 : DEMOGRAPHY

Sources of Demographic data, coverage and content errors. Use of balancing equation and Chandrasekharan Deming formula to check completeness of registration data. Use of Whipple's Myres' Baachi's and UN indices.

Measures of fertility - period and cohort measures. Use of birth order Statistics and child - Woman ratio. Brass' technique to estimate current fertility levels. Estimation of TFR age pattern of fertility, differential fertility. Measures of reproduction and replacement.

Measures of mortality - standard death rates, neo-natal, perinatal death rates, maternal and infant mortality rates standardization of mortality rates. Construction of complete and abridged life tables. Expectation of life Use's and application of life tables.

Rates and ratios of Migration Methods of estimating the volume of migration - Vital statistics method and survival ratio methods. Measurement of population growth. Population estimates and projections.

Stable and quasi stable population analysis. Statistical models for population growth. Mathematical models in mortality, fertility and human reproductive process.

REFERENCE:

1. Barclay, G.W : Techniques of population analysis, John Wiley and Sons.
2. Spiegelman, H. : Introduction to Demography Harvard University press
3. Keyfitz, N. : Introduction to the mathematics of population; Addison - Wesley Publishing co.,
4. Pollard, J.H : Mathematical Models for the growth of human population Cambridge University Press.
5. Biswas, S. : Stochastics Processes in Demography and applications Wiley Eastern Ltd.
6. Chiang, C.L. : Introduction to Stochastic Processes in Biostatistics, John Wiley and Sons.
7. Ravikumar, R. : Technical demography Wiley Eastern Ltd.,
8. Wolfenden, H.H : Population Statistics and their compilation, American Actuarial Society.
9. United Nations Manuals : II, III, IV, VI, VII.

ST. 410: STOCHASTIC PROCESSES

Introduction to stochastic processes (sp's); classification of sp's according to state space and time domain. Countable state Markov chains (MC's), Chapman-Kolmogorov equations; calculation of n-step transition probability and its limit. Stationary distribution, classification of states; transient MC; Random walk and gambler's ruin problem;

Applications from social, biological and physical sciences. (12 L)

Discrete state space continuous time MC: Kolmogorov- Feller differential equations; Poisson process, birth and death process; Applications to queues and storage problems. Wiener process as a limit of random walk; first -passage time and other problems. (8 L)

Renewal theory: Elementary renewal theorem and applications. Statement and uses of key renewal theorem; study of residual life time process. Stationary process: weakly stationary and strongly stationary processes; Moving average and auto regressive processes (10 L)

Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size. Martingale in discrete time, inequality, convergence and smoothing properties. Statistical inference in MC and Markov processes. (15 L)

Total: (45 L), (15 T).

REFERENCES

1. Adke, S. R. and Manjunath, S. M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.

2. Bhat, B. R. (2000): Stochastic Models: Analysis and Applications, New Age International, India.
3. Cinlar, E. (1975): Introduction to Stochastic Processes, Prentice Hall.
4. Feller, W. (1968): Introduction to Probability and its Applications, Vol. 1, Wiley Eastern.
5. Harris, T.E. (1963): The Theory of Branching Processes, Springer-Verlag.
6. Hoel, P.G., Port, S.C. and Stone, C.J. (1972): Introduction to Stochastic Processes, Houghton Mifflin & Co.
7. Jagers, P. (1974): Branching Processes with Biological Applications, Wiley.
8. Karlin, S. and Taylor, H. M. (1975): A First Course in Stochastic Processes, Vol. 1, Academic Press.
9. Medhi, J. (1982): Stochastic Processes, Wiley Eastern
10. Parzen, E. (1962): Stochastic Processes, Holden-Day.

CHOICE BASED PAPER " STATISTICAL METHODS AND APPLICATIONS "

DESCRIPTIVE STATISTICS:

BSB

Collection of data, Tabular and graphical representation of data, Attribute and Variable discrete and continuous. Analysis of data - Frequency distribution, Histogram and Ogive Measures of location, dispersion/scale and skewness. Bivariate data - scatter diagram, Product moment correlation and linear regression, Spearman's rank correlation.

PROBABILITY THEORY:

Concepts of Probability, Standard Probability Distributions - Binomial Poisson, Geometric, Exponential normal t, F and Chi-square and properties.

SAMPLING:

Population and sample - simple random sampling. drawing random samples using random tables. Concepts of stratified random sampling. Standard error of sample mean and sample proportion.

STATISTICAL INFERENCE:

BSB

Testing for means, proportions and variance in one sample and two sample problems. Chi-square test for attributes. Analysis of variance - principles - one way and two way classification models

BOOKS FOR STUDY AND REFERENCE:

1. Goon A.M, Gupta M.K and Das Gupta B: Fundamental of Statistics Vol.1 and II. World Press Pvt. Ltd., Calcutta.

2. Bhattacharya G.K. and Johnson R.A. *Statistical concepts and Methods*. Wiley Eastern. Calcutta, Bombay and Delhi.
3. Levin R.I : *Statistics for Management*. Prentice Hall of India, New Delhi.
4. Hines W.W. and Montgomery D.C: *Probability and Statistics – In Engineering and Management Science*. Ronal Press, New York.
5. Medhi J: *Statistical Methods*. Wiley Eastern Limited, New Delhi.

CHOICE BASED PAPER “ PROBABILITY THEORY AND MATHEMATICAL STATISTICS ”

Review of set theory and calculus.

PROBABILITY THEORY:

Axiomatic Probability, Random Variables and distributions. Expectation and moments. Standard discrete and continuous probability models. Sampling distributions. Modes of convergence, WLLN, SLLN AND CLT with applications (SLLN and CLT - statements only)

STATISTICAL METHODS:

Measures of central tendency and dispersion. Correlation and regression - curve fitting.

STATISTICAL INFERENCE:

Parameters and estimates. Methods of estimation - moment, maximum Likelihood Properties of estimators - Unbiasedness, MSE and consistency. Interval estimation. Testing of hypotheses - Basic concepts of testing, Neyman - Pearson lemma (Statement only) and examples. Likelihood Ratio Tests - One sample and two sample problems.

BOOKS FOR STUDY AND REFERENCE:

1. Rohatgi, V.K: *An introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern.
2. Hogg, R.V. and Tanis, E.A: *Probability and Statistical Inference*. Mc.Millan, New York.
3. Hogg, R.V. and Craig: *Introduction to Mathematical Statistics*, Mc Millan, New York.
4. Feller, W: *Introduction to Probability Theory*, Vol I, Wiley
5. Freund, J.E: *Modern Elementary Statistics*, Prentice Hall of India, New Delhi.