Syllabus
M. A. / M.Sc. (Statistics)
Department of Statistics
Mahatma Kashi Vidyapith
Varanasi

Semester wise distribution of Courses

There shall be four theory papers of 100 marks each and a practical/project of 100 marks in each semester.

SEMESTER - I

Paper	Title	Marks
101	***Real Analysis and Linear Algebra***	**100**
102	***Statistical Inference – I***	**100**
103	***Linear Models and Regression Analysis***	**100**
104	***Sampling Theory I***	**100**
105	***Practical based on the contents of theory papers***	**100**
	Total	**500**

SEMESTER - II

Paper	Title	Marks
201	***Distribution Theory***	**100**
202	***Statistical Inference – II***	**100**
203	***Design and Analysis of Experiments***	**100**
204	***Sampling theory II***	**100**
205	***Practical based on the contents of theory papers***	**100**
	Total	**500**

SEMESTER – III

Paper	Title	Marks
301	***Measure and Probability***	**100**
302	***Multivariate Analysis***	**100**
303	***Stochastic Processes***	**100**
304	***Operations Research***	**100**
305	***Practical based on the contents of theory papers***	**100**
	Total	**500**

SEMESTER – IV

Select any four electives from 401 to 411.

Paper	Title	Marks
401	***Actuarial Statistics***	**100**
402	***Advanced Multivariate Analysis***	**100**
403	***Advanced Operations Research***	**100**
404	***Bayesian Inference***	**100**
405	***Computer Programming in C***	**100**
406	***Econometrics***	**100**
407	***Demography***	**100**
408	***Reliability***	**100**
409	***Statistical Decision Theory***	**100**
410	***Statistical Processes and Quality Control***	**100**
411	***Survival Analysis***	**100**
412	***Practical based on the contents of theory papers of electives***	**100**
	Total	**500**

SEMESTER - I

101: ***Real Analysis and Linear Algebra***

UNIT - I

Recap of elements of set theory; Introduction to real number, introduction to n-dimensional Euclidian space, open and closed intervals (rectangles), compact sets, Bolzano-Weirstrass theorem, closed, open and compact sets and their properties, Heine - Borel theorem.

UNIT - II

Real valued functions, continuous functions, Uniform continuity, sequences of functions, uniform convergence, Power series and radius of convergence, Riemann Integration, Mean value theorems of integral calculus.

UNIT - III

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.

Vector space with an inner product, Gram-Schmidt orthogonalization process, orthonormal basis and orthogonal projection of a vector.

UNIT - IV

Real quadratic forms, reduction and classification of quadratic forms, index and signature. Characteristic roots and vectors, Caley-Hamilton theorem, minimal polynomial, similar matrices, algebraic and geometric multiplicity of a characteristic root, spectral decomposition of a real symmetric matrix.

References:

1. Apostol, T. M. (1985): Mathematical Analysis, Narosa, Indian Ed.
2. Bellman R. (1970): Introduction to Matrix Analysis, 2nd ed. Mc Graw Hill.
3. Bhimsankaran P. (1992): Linear Algebra, Tata McGraw Hill Publishing Company Ltd.
4. Biswas, S. (1984): Topics in Algebra of Matrices, Academic Publications.
5. Courant, R. and John, F. (1965): Introduction to Calculus and Analysis, Wiley.
6. Graybill, F. A. (1983): Matrices with applications in Statistics, 2nd Ed. Wadsworth.
7. Hadley G. (1987): Linear Algebra: Narosa Publishing House.
8. Halmos, P. R. (1958): Finite-dimensional Vector Spaces, 2nd ed. D. Van Nostrand Company, Inc.
9. Hoffman K. & Kunze, R. (1971): Linear Algebra, 2nd ed., Prentice Hall, Inc.
10. Rao A. R. and Miller, K. S. (1957): Advanced Real Calculus, Harper, New York.
11. Rudin, Walter (1976): Principles of Mathematical Analysis, McGraw
12. Shanti Narain: A Course in Mathematical Analysis, S. Chand and Company (Pvt.) Ltd.
13. Shanti Narain: A text book of matrices, S. Chand and Company (Pvt.) Ltd.
14. Rao C. R. (1973): Linear Statistical inference and its applications 2nd ed. John Wiley & Sons, Inc.
15. Rao C. R. and Mitra S. K. (1971): Generalized Inverse of Matrices and Its Applications, John Wiley & Sons, Inc.
16. Searle S. R. (1982): Matrix Algebra Useful for Statistics, John Wiley & Sons, Inc.

102: *Statistical Inference – I*

UNIT - I

Extension of Cramer-Rao inequality for multi-parameter case, Bhattacharya bounds, information in data about the parameters as variation in likelihood function.

UNIT - II

Ideas of sufficient and minimal complete-sufficient statistics, sufficiency when the range of variate depends on parameter. Minimum variance unbiased estimators, Rao-Blackwell and Lehman-Scheffe theorems.

UNIT - III

Maximum likelihood estimators and its asymptotic properties, solution of likelihood equations, method of scoring.

UNIT - IV

General decision problems, loss function, risk function, estimation and testing viewed as general decision problems, minimax decision, Bayes decision, least favourable prior, Bayes minimax estimator and posterior estimation under squared error loss, some simple illustrations based on binomial, Poisson, and normal distributions, procedure for obtaining minimax estimators from Bayes estimators.

References:

1. Kale, B. K. (1999): A First Course on Parametric Inference, Narosa Publishing House.
2. Rohatgi, V. K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi.
3. Lehmann, E. L. (1986): Theory of Point Estimation, Student Edition.
4. Lehmann, E. L. (1986): Testing Statistical Hypotheses, Student Editions.
5. Rao, C. R. (1973): Linear Statistical Inference and its Applications, Wiley Eastern.
6. Ferguson, T. S. (1967): Mathematical Statistics, Academic Press.
7. Zacks, S. (1971): Theory of Statistical Inference, Wiley, New York.

103: ***Linear Models and Regression Analysis***

UNIT- I

Grauss-Markov linear models, estimable functions, error and estimation space, normal equations and least square estimates, Variance and covariance of the estimates, Gauss-Markoff's theorem (estimation of error variance).

UNIT- II

Generalized inverse of a matrix, Linear estimation with correlated variables (observations), contrasts and orthogonal contrasts with examples.

UNIT- III.

One way and two-way classifications, fixed, random and mixed effects models. Analysis of variance (two-way classification with one observation per cell only), multiple comparison tests due to Tukey, Scheffe and Student-Newmann-Keul.

UNIT-IV

Simple linear regression, multiple linear regression, orthogonal polynomials, fit of polynomials and use of orthogonal polynomials. Tests of hypothesis under linear regression model.

References:

1. Goon, A. M., Gupta, M. K. and Das Gupta, B. (1967): An Outline of Statistical Theory, Vol. 2, The World Press Pvt. Ltd., Calcutta.
2. Rao, C. R. (1973); Linear Statistical Inference and its Application, Wiley Eastern.
3. Graybill, I. A. (1961): An Introduction to Linear Statistical Models, Vol. 1, McGraw Hill Book Co. Inc.
4. Draper, N. R. and Smith H. (1998); Applied Regression Analysis, 3rd Ed. Wiley.
5. Weisberg, S. (1985): Applied Linear Regression, Wiley.
6. Cook, R. D. and Weisherg, S. (1982): Residuals and Inference in Regression, Chapman and Hall.
7. Mukhopadhyay, Parimal (2000): Mathematical Statistics. Douglas C. Montgomery, Elizabeth A. Peck, G. Geoffery Vining: Introduction to linear regression analysis.

104: ***Sampling Theory I***

UNIT - I

Allocation problem in stratified random sampling in case of fixed cost and also for specified precision, expression for variance of stratified mean in case of fixed cost, post stratification, estimation of gain in precision due to stratification over simple random sampling.

UNIT - II

Review of important results in ratio and regression method of estimation, ratio method of estimation in stratified random sampling, regression estimators in stratified random sampling, unbiased ratio type estimators, product estimator.

UNIT - III

Cluster sampling with equal clusters, estimates of population mean and their variances, efficiency of cluster sampling in term of intraclass correlation coefficient, two stage sampling with equal number of second stage units.

UNIT - IV

Concept of double sampling, double sampling for stratification, double sampling for ratio and regression estimators.

References:

1. Cassel, C. M., Sarndal, C. E. and Wretman (1977): Foundation of Inference in Survey Sampling, Wiley Inter Science, New York.
2. Choudhari A. and Vos, J. W. E. (1988): Unified Theory of Strategies of Survey Sampling, North Holland, Amsterdam.
3. DesRaj (2000): Sample Survey Theory, Narosa Publishing House.
4. Hedayat, A. S. and Sinha, B. K. (1991): Design and Inference in Finite Population Sampling, Wiley.
5. Murthy, M. N. (1977): Sampling Theory and Methods. Statistical Publication Society, Calcutta.
6. Mukhopadhyay, P. (1996): Inferential Problems in Survey Sampling, New Age International (P).
7. Sukhatme, P. V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984): Sampling Theory of Surveys with Applications, Iowa State University Press and Indian Society of Agricultural Statistics.
8. Chaudhuri, A. and R. Mukherjee (1988): Randomised response: theory and techniques, New York, Marcel Deckker Inc.
9. Cochran, W. G.: Sampling Techniques (3rd edition. 1977), Wiley.
10. Singh D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, New Age International Publishers.

105*: Practical*

Based on the contents of theory papers.

SEMESTER - II

201: ***Distribution Theory***

UNIT – I

Brief review of basic distribution theory. Joint, marginal and conditional p.m.f. and p.d.f. Discrete and continuous distributions. Bivariate normal and exponential, multivariate normal and multinomial distributions. Functions of random variables and their distributions using Jacobian of transformation and other tools.

UNIT - II

Compound, truncated and mixture distributions. Conditional expectation, correlation, multiple and partial correlation. Linear and multiple regression.

UNIT - III

Approximating distributions of sample moments. Transformation of statistics. Sampling distributions. Non-central chi-square, t- and F- distributions and their properties. Distributions of quadratic forms under normality and related distribution theory.

UNIT - IV

Order statistics with their distributions and properties. Joint and marginal distributions of order statistics. Extreme values and their asymptotic distributions (Statement only) with applications.

References:

1. Dudewicz, E. J. and Mishra, S. N. (1988): Modern Mathematics Statistics, Wiley International Student's edition.
2. Rohatagi, V. K. (1984): An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
3. Rao, C. R. (1973); Linear Statistical Inference and its Applications, Wiley Eastern.
4. Pitman, J. (1993): Probability, Narosa Publishing House.
5. Jonson, S. and Kotz, S. (1972): Distribution in Statistics Vol. I-II & III, Houghton and Mifflin.

202: ***Statistical Inference – II***

UNIT - I

Consistent Asymptotic normal estimators and their properties, CAN estimators obtained by ML method in one parameter exponential case, Invariant estimators, Location and scale invariant estimators, Pitman's method for obtaining location and scale invariant estimators.

UNIT - II

Interval estimation by confidence sets, Neyman theory, general method for constructing confidence intervals, shortest confidence intervals, uniformly most accurate intervals, Bayes intervals, with examples based on normal distribution.

UNIT -III

Neyman-Pearson lemma, generalized Neyman-Pearson lemma, monotone likelihood ratio families, UMP tests for one and two sided alternatives, admissibility and unbiasedness of tests, type A and type A_1 tests, similar tests, tests having Neyman structure.

UNIT - IV

Likelihood ratio test (LRT), asymptotic distribution of LRT statistic. Wald's sequential probability ratio test and its properties, OC and ASN function, derivation of OC and ASN functions.

References:

1. Kale, B. K. (1999): A First Course on Parametric Inference, Narosa Publishing House.
2. Rohatgi, V. K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi.
3. Lehmann, E. L. (1986): Testing Statistical Hypotheses, Student Editions.
4. Rao, C. R. (1973): Linear Statistical Inference and its Applications, Wiley Eastern.
5. Ferguson, T. S. (1967): Mathematical Statistics, Academic Press.
6. Zacks, S. (1971): Theory of Statistical Inference, Wiley, New York.
7. Dudewicz, E. J. and Mishra, S. N. (1988): Modern Mathematics Statistics, Wiley International Students'edition.

203: ***Design and Analysis of Experiments***

UNIT - I

Review of linear estimation and basic designs, missing plot technique: General theory and applications, Analysis of variance for CRD and RBD, analysis of two-way orthogonal and non-orthogonal data, multiple comparison tests due to Tukey, Student-Newman-Keul.

UNIT - II

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 partial confounding, construction of symmetrical confounded factorial experiments.

UNIT - III

Incomplete block design: Balanced incomplete block designs, simple lattice designs (BIBD), resolvability and parametric relations of BIBD, split plot experiments.

UNIT - IV

Partially balanced incomplete block designs (PBIBD), parametric relations in PBIBD, classification of PBIBD with two associate classes, intra block analysis of PBIBD. Analysis of covariance in RBD.

References:

1. Aloke 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. & 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, Mc Millan.
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. Meyer, R. H. (1971): Response surface methodology. Allyn & Bacon.
9. Nigm, Puri & Gupta (1987-88): Characterisation and Analysis of Block Design, Wiley Eastern.
10. Pearce, S. C. (1984): Design of experiments Wiley, New York.
11. Raghava Rao D. (1971): Construction and Combinatorial problems in Design of experiment. Wiley.
12. Rao, C. R. and Kleffe, J. (1988): Estimation of Variance Components and applications, North Holland.
13. Searle, S. R., Casella, G. and Mc Culloch, C. E. (1992): Variance Components, Wiley.
14. V. K. Gupta & A. K. Nigam (1978-79): Handbook an analysis of Agriculture Experiment, IASRI Publication.

204: ***Sampling theory II***

UNIT - I

Cluster sampling with unequal sizes of clusters, two stage sampling with unequal number of second stage units, sampling with replacement and unequal probabilities, estimate of the mean and its variance.

UNIT - II

Sampling with varying probabilities PPSWR/WOR methods (including Lahiri's scheme) and related estimators of finite population mean.

UNIT - III

Concept of ordered and unordered estimators, Hansen-Hurwitz and Des Raj estimators for general sample size and Murthy's estimator for a sample of size 2, Horvitz-Thompson estimator (HTE) for finite population total/mean, expression for V(HTE) and its unbiased estimator, issues in non-negative variance estimation, IIPS schemes of sampling due to Midzunosen.

UNIT - IV

Non sampling errors and biased responses, randomized responses for variables, errors in surveys, modeling observational errors, estimation of variance components, non-response errors, Hansen and Hurwitz technique for non response .

References:

1. Cassel, C. M., Sarndal, C. E. and Wretman (1977): Foundation of Inference in Survey Sampling, Wiley Inter Science, New York.
2. Choudhari A. and Vos, J. W. E. (1988): Unified Theory of Strategies of Survey Sampling, North Holland, Amsterdam.
3. DesRaj (2000): Sample Survey Theory, Narosa Publishing House.
4. Hedayat, A. S. and Sinha, B. K. (1991): Design and Inference in Finite Population Sampling, Wiley.
5. Murthy, M. N. (1977): Sampling Theory and Methods. Statistical Publication Society, Calcutta.
6. Mukhopadhyay, P. (1996): Inferential Problems in Survey Sampling, New Age International (P).
7. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S. and Asok, C. (1984): Sampling Theory of Surveys with Applications, Iowa State University Press and Indian Society of Agricultural Statistics.
8. Chaudhuri, A. and R. Mukherjee (1988): Randomised response: theory and techniques, New York, Marcel Deckker Inc.
9. Cochran, W. G.: Sampling Techniques (3rd edition. 1977), Wiley.
10. Singh D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, New Age International Publishers.

205: ***Practical***

Based on the contents of theory papers.

SEMESTER – III

301: ***Measure and Probability***

UNIT-I

Classes of sets, fields, sigma fields, minimal sigma field, Borel sigma field, sequence of sets, lim sup and lim inf of a sequence of sets, measure, probability measure, properties of measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue - Steiltzes measures.

UNIT-II

Measurable functions, Integration of measurable function with respect to a measure, monotone convergence theorem, Fotou's lemma, Dominated convergence theorem (statement only). Random variables, sequence of random variables, almost sure convergence, convergence in probability and in measure, convergence in r^{th} mean, convergence in distribution.

UNIT- III

Weak law and strong law of large numbers for independently and identically distributed sequences. Borel-Cantelli lemma, Kolmogorov's inequality.

UNIT-IV

Characteristic function, uniqueness theorem, Levy's continuity theorem (statement only),Inversion theorem, CLT for a sequence of independently and identically distributed random variables under De-moivre and Laplace, Lindeberg- Levy condition, Liapounov's CLT for a sequence of independent random variables.

References:

1. Robert, A. (1972): Real Analysis and Probability, Acad.
2. Basu, A. K. (2012): Measure Theory and Probability, PHI, New Delhi.
3. Bhat, B. R.: Modern Probability Theory.
4. Billingsley, P. (1986). Probability and Measure. Wiley.
5. Goon, A. M., Gupta, .K. and Dasgupta, B. (1991): Fundamentals of Statistics Vol. I, World Press, Calcutta.
6. Kingman, J. F. C. and Taylor, S. J. (1966). Introduction to Measure and Probability. Cambridge University Press.
7. Parthasarathy, K. R. (1967): Probability Measures on Metric Spaces, Academic Press.
8. Pitman, J. (1993): Probability, Narosa Publishing House.
9. Rohatgi, V. K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi.
10. Ferguson, T. S. (1967): Mathematical Statistics, Academic Press.

302: ***Multivariate Analysis***

UNIT - I

Matrix theory: Inverse of partitioned matrices, g inverse, Orthogonal matrices, properties of idempotent matrices, characteristic roots and vectors, Cayley- Hamilton theorem, Quadratic forms.

UNIT - II

Multivariate normal distribution, Characteristic function, Random sampling from a multivariate normal distribution. Maximum likelihood estimators of parameters.

UNIT - III

Null and non-null distribution of simple correlation coefficient. Null distribution of partial and multiple correlation coefficient. Distribution of sample regression coefficients. Application in testing and interval estimation.

UNIT - IV

Wishart matrix, its distribution and properties. Distribution of sample generalized variance Null distribution of Hotelling's T^2 statistic. Mahalonobis distance. Distribution of sample mean vector.

References:

1. Anderson, T. W. (1983): An Introduction to multivariate statistical analysis. 2nd Ed. Wiley.
2. Giri, N. C. (1977): Multivariate Statistical inference. Academic Press.
3. Kshirsagar, A. M. (1972): Multivariate Analysis. Marcel Dekker.
4. Morrison, D. F. (1976): Multivariate statistical methods. 2nd. Ed. McGraw Hill.
5. Muirhead, R. J. (1982): Aspects of multivariate statistical theory, J. Wiley.
6. Rao, C. R. (1973): Linear statistical inference and its applications. 2nd Ed. Wiley.
7. Seber, G. A. F. (1984): Multivariate observations. Wiley.
8. Sharma, S. (1996): Applied multivariate techniques. Wiley.
9. Srivastava, M. S. and Khatri, C. G. (1979): An introduction to multivariate statistics. North Holland.
10. Johnson, R. and Wychern (1992): Applied multivariate Statistical analysis, Prentice Hall, 3rd Ed.

303: ***Stochastic Processes***

UNIT-I

Introduction to stochastic processes: Classification of according to state space and time domain, Countable state Markov chains, Chapman-Kolmogorov equations; calculation of n-step transition probability and its limit. Stationary distribution, classification of states of Markov chains.

UNIT-II

Discrete state space continuous time MC: Kolmogorov – Feller differential equations, Poisson process, birth process, Death process, birth and death process.

UNIT-III

Random walk and gambler's ruin problem. Wiener process as a limit of random walk, Differential equation and first passage time distribution. Renewal theory: Renewal function, renewal equation, Elementary renewal theorem and applications. Statement and uses of key renewal theorem, study of residual life time to a fixed point.

UNIT-IV

Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of total number of progeny, Martingale in discrete time queueing theory: queueing models, differential equation of distribution of birth –death process, M/M/1 queue, M/M/s queue.

References:

1. Adke, S. R. and Manjunath, S. M. (1984): An Introduction to Finite Markov Processes, Willey Eastern.
2. Bharat, 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 Miffin & 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.
11. Srinivasan, S. K. and Mehata, K. M.: Stochastic processes.

304: ***Operations Research***

UNIT - I

Game Theory: 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 solution in 2×2, 2×m and m×n games; reduction of game problem to a linear programming problem.

UNIT - II

Review of linear programming problems (LPP); revised simplex method; duality theorem; bounded variable problems. Allocation Problems: transportation problem (TP); degeneracy in TP; unbalanced TP.

UNIT - III

Integer Programming: Branch and bound algorithm and cutting plane algorithm. 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. Inventory models with random demand.

UNIT - IV

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; steady-state solutions of $M/E_K/1$ and $E_K/M/1$ queues; machine interference problem.

References:

1. Saaty, T. L. (1961): Elements of Queuing Theory with Applications; McGraw Hill.
2. Gross, D. and Harris, C. M. (1974): Fundamentals of Queuing Theory, John Wiley.
3. Hadley, G. (1964): Non-Linear and Dynamic Programming; Addison Wesley.
4. Taha, H. A. (1982): Operations Research: An Introduction; Mac Millan Publishing Company, New York.
5. Kanti Swaroop, Gupta, P. K. and Singh, M. M. (1985): Operations Research, Sultan Chand and Sons.
6. Philips, D. T., Ravindran, A. and Solberg, J.: Operations Research, Principles and Practice.
7. Mckinsey, J. C. C. (1952): Introduction to the Theory of Games; McGraw Hill.
8. Hadley, G. and Whitin, T. M. (1963): Analysis of Inventory Systems; Prentice Hall.

305: ***Practical***

Based on the contents of theory papers.

SEMESTER – IV

Select any four electives from 401 to 411.

401: *Actuarial Statistics*

UNIT – I

Utility theory, insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality. Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables. Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws.

UNIT – II

Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations. Distribution of aggregate claims, compound Poisson distribution and its applications. Distribution of aggregate claims, compound Poisson distribution and its applications.

UNIT – III

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding. Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

UNIT – IV

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities. Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits. A brief outline of payment premiums and net premiums

References:

1. N. L. Bowers, H. U. Gerber, J. C. Hickman, D. A. Jones and C. J. Nesbitt (1966): Actuarial Mathematics, Society of Actuarials, Ithaca, Illinois, U. S. A., Second Edition (1997).
2. Spurgeon, E. T. (1972): Life Contingencies, Cambridge University Press.
3. Neill, A. (1977): Life Contingencies, Heinemann.

402: ***Advanced Multivariate Analysis***

UNIT - I

Tests on mean vector for one and more multivariate normal populations and also on equality of the components of a mean vector in a multivariate normal population. James-Stein estimator of the mean vector and improved estimation of dispersion matrix of a multivariate normal distribution.

UNIT - II

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.

UNIT - III

Distribution of characteristic roots and vectors of Wishart matrices, Principal components, Dimension reduction, Canonical variables and canonical correlation - definition, use, estimation and computation.

UNIT - IV

Factor analysis, Linear factor models, Estimation of factor loadings, Factor rotation, Estimation of factor scores, Testing goodness of fit.

References:

1. Anderson T. W. (1984): An introduction to multivariate statistical analysis, 2nd Ed., J. Wiley.
2. Eaton M. L. (1983): Multivariate statistics-a vector space approach, J. Wiley.
3. Giri N. C. (1977): Multivariate statistical inference, Academic Press.
4. Kshirsagar A. M. (1972): Multivariate analysis, Marcel Dekker.
5. Morrison D. F. (1976): Multivariate statistical methods, McGraw Hill.
6. Muirhead, R. J. (1982): Aspects of multivariate statistical theory, J. Wiley.
7. Rao C. R. (1973): Linear statistical inference and its applications, J. Wiley.
8. Roy S. N. (1957): Some aspects of multivariate analysis, J. Wiley.
9. Srivastava M. S. and Khatri C. G. (1979): An introduction to multivariate statistics, North Holland.

403: ***Advanced Operations Research***

UNIT - I

Dynamic Programming: Bellman's principle of optimality; general formulation of dynamic programming, computational methods and applications of dynamic programming. Goal programming.

UNIT - II

Non-Linear Programming: Kuhn-Tucker conditions; Wolfe's and Beale's algorithms for solving quadratic programming problems.

UNIT - III

Sequencing and scheduling problems: 2 machine n-job and 3–machines n-job problems with identical machine sequence for all jobs; 2-job n-machine problem with different routings; branch and bound method for solving travelling-salesman problem. Project management: CPM and PERT; probability of project completion; PERT-crashing.

UNIT - IV

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

References:

1. Taha, H. A. (1982): Operations Research: An Introduction; MacMillan Publishing Company, New York.
2. Hillier, F. S. and Leiberman, G. J. (1962): Introduction to Operations Research; Holden Day.
3. Kanti Swaroop, Gupta, P. K. and Singh, M. M. (1985): Operations Research; Sultan Chand and Sons.
4. Churchman, C. W.; Ackoff, R. L. and Arnoff, E. L. (1957): Introduction to Operations Research; John Wiley.
5. Mckuisey, J. C. C. (1952): Introduction to the Theory of Games, McGraw Hill.
6. Kleinrock, L. (1975): Queueing Systems, Vol. I; John Wiley.
7. Hadley G. and Whitin, T. M. (1963): Analysis of Inventory Systems; Prentice Hall.
8. Starr, M. K. and Miller, D. W. (1962): Inventory Control – Theory and Practice; Prentice Hall.
9. Shamblin, J. E. and Stevens, G. T. (1974): Operations Research: A Fundamental Approach; McGraw Hill.

404: ***Bayesian Inference***

UNIT – I

Subjective interpretation of probability in terms of fair odds. Bayes theorem and computation of the posterior distribution. Natural conjugate family of priors. Hyper parameters of a prior from conjugate family. Conjugate family for (i) exponential family models (ii) models admitting sufficient statistics for fixed dimension. Non informative, improper and invariant priors. Jeffery's prior.

UNIT – II

Bayesian decision theory : Bayes solutions for practical decision problems. Bayesian point estimation as a prediction problem from posterior distribution, Bayes estimators for (i) absolute error loss (ii) squared error loss (iii) 0 -1 loss. Generalization to convex loss functions. Evaluation of the estimates in the terms of the posterior risks.

UNIT – III

Bayesian interval estimation: credible intervals, highest posterior density regions, Interpretation of the confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval.

UNIT – IV

Bayesian testing Hypothesis : Specification of the appropriate from of the prior distribution for a Bayesian testing of hypothesis problem, Prior odds, Posterior odds, Bayes factor for various types of testing problems depending upon weather the null hypothesis and alternative hypothesis are simple or composite. Specification of the Bayes test in above cases. Discussion of Lindley's paradox for testing a point hypothesis for normal mean against the two sided alternative hypothesis.

References:

1. Berger, J. O.: Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
2. Robert, C. P. and Casella, G.: Monte Carlo Statistical Methods, Springer Verlag.
3. Leonard, T. and Hsu, J. S. J.: Bayesian Methods, Cambridge University Press.
4. Bernando, J. M. and Smith, A. F. M.: Bayesian Theory, John Wiley and Sons.
5. Robert, C. P.: The Bayesian Choice: A Decision Theoretic Motivation, Springer.
6. Gemerman, D.: Markov Chain Monte Carlo: Stochastic Simulation for Bayesian Inference, Chapman Hall.
7. Box, G. P. and Tiao, G. C.: Bayesian Inference in Statistical Analysis, Addison-Wesley.

405: ***Computer Programming in C***

UNIT-I

Structure of a C program, input statement, numeric constants and variables, arithmetic expressions, some simple programmes. Input and output programs: input functions, output functions, Conditional/Decision control structures: if, if-else, nested if-else, use of conditional statement such as in picking largest of 3 numbers, to solve the quadratic equations.

UNIT-II

Loop control structures: while, for and do-while ,uses of loop structures in solving the problems such as calculation of simple interest for different sets of inputs, etc., break and continue statements. Case control structures: switch, go to and their uses to solve a quadratic equation.

UNIT-III

Arrays: definition of array and simple program using array, two dimensional arrays, reading and writing two-dimensional arrays, addition, subtraction, multiplication of two matrices, transpose of a matrix, calculation of correlation coefficient, mean and standard deviation.

Strings: definition of string, standard library string functions: strlen(), strcpy(), strcpy(), strcat(), strrev() and their uses, two dimensional array of characters.

UNIT-IV

Function: definition and uses of function to reverse a given number, adding digits of an integer, calculation of simple interest.

Structures data types: declaration and assessment of structure elements, array of structures, uses of structures.

References:

1. Balagurusamy, E.: Programming in ANSI C. Tata McGraw Hill.
2. Gottfried, Byron S. : Theory and problems of programming with C. TMH
3. Kanetkar, Y. P.: Working with C. BPB Publication.
4. Schildt, Herbert : C : The complete reference III Ed.. TMH.
5. Schildt, Herbert : C Made easy. Mc Graw Hill.
6. V. Rajaraman : Computer programming in C.
7. Yashavant P. Kanetkar: Let us C.

406: ***Econometrics***

UNIT - I

Nature of econometrics. Linear regression model, assumptions, estimation of parameters by least squares and maximum likelihood methods, test of hypothesis and confidence estimation for regression coefficients, R^2 and adjusted R^2 , Use of extraneous information in terms of exact and stochastic linear restrictions, restricted restriction and mixed regression methods and their properties, point and interval predictors.

UNIT - II

Tests for structural change, use of dummy variables, problem of multicollinearity, consequences and solutions, estimation of parameters by Genrelized least squares in models with non spherical disturbances Hetroscedasticity of disturbances, estimation under hetroscedasticity and test for hetroscedasticity.

UNIT - III

Autocorrelation, Durban- Watson test, Estimation under autocorrelated disturbances Errors in variables model, inconsistency of least squares method Instrumental variable method.

UNIT - IV

Seemingly unrelated regression equation(SURE) model and its estimation, simultaneous equation model, concept of structural and reduced forms, problem of identification, rank and order conditions of identifiability, indirect least squares, two stage least squares and limited information maximum likelihood estimation, idea of three stage least squares.

References:

1. Apte P. G. (1990); Text book of Econometrics. Tata McGraw Hill.
2. Cramer, J. S. (1971): Empirical Econometrics, North Holland.
3. Gujarathi, D. (1979): Basic Econometrics, McGraw Hill.
4. Intrulligator, M. D. (1980): Econometric models - Techniques and applications, Prentice Hall of India.
5. Johnston, J. (1984): Econometric methods, Third edition, McGraw Hill.
6. Klein, L. R. (1962): An introduction to Econometrics, Prentice Hall of India.
7. Koutsoyiannis, A. (1979): Theory of Econometrics, Macmillan Press.
8. Malinvaud, E (1966): Statistical methods of Econometrics, North Holland.
9. Srivastava, V. K. and Giles D. A. E. (1987): Seemingly unrelated regression equations models, Maicel Dekker.
10. Theil, H. (1982): Introduction to the theory and practice of Econometrics, John Wiley.
11. Walters, A (1970): An introduction to Econometrics, McMillan & Co.
12. Wetherill, G. B. (1986): Regression analysis with applications, Chapman Hall.

407: *Demography*

UNIT – II

Coverage and content errors in demographic data, use of the balancing equations and Chandrasekharan—Deming formula to check completeness of registration data, adjustment of age data and the use of Whipple, Myer and UN indices.

UNIT – II

Nuptiality and its measurements. Measures of fertility; stochastic models for reproduction, distributions of time of birth, inter-live birth intervals and number of births (for both homogeneous and non-homogeneous groups of women).

UNIT – III

Measures of Mortality; infant mortality rate and its adjustments, model life table, construction of abridged life tables, distributions of life table functions and their estimation.

Stable and quasi-stable populations, intrinsic growth rate. Models of population growth and their filling to population data.

UNIT – IV

Internal migration and its measurement, migration models, concept of international migration. Methods for population projection, component method of population projection.

References:

1. Kumar, R. (1986): Technical Demography, Wiley Eastern Ltd.
2. Benjamin, B. (1969): Demographic Analysis, George, Allen and Unwin.
3. Chiang, C. L. (1968): Introduction to Stochastic Progression.
4. Cox, P. R. (1970): Demography, Cambridge University Press.
5. Keyfitz, N. (1977): Introduction to the Mathematics of Population-with Revisions, Addison-Wesley, London.
6. Spiegelman, M. (1969): Introduction to Demographic Analysis, Harvard University Press.
7. Wolfenden, H. H. (1954): Population Statistics and Their Compilation, Am Actuarial Society.

408: ***Reliability Theory***

UNIT - I

Reliability concepts and measures; components and systems; coherent systems; Reliability of coherent system; cuts and paths; modular decomposition; bounds on system reliability; structural and reliability importance of components.

UNIT - II

Life distributions; reliability function; hazard rate; common life distributions – exponential, Weibull, gamma, normal, etc.; Estimation of parameters and tests in these models. Notions of aging; 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; convolution and mixtures.

UNIT - III

Basic ideas of accelerated life testing. Univariate shock models and life distribution arising out of them; bivariate shock models; common bivariate exponential distributions and their properties. Maintenance and replacement policies; availability of reparable systems; modelling of a repairable system by a non-homogeneous Poisson process.

UNIT - IV

Reliability estimation based on failure times in variously censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation. Reliability growth models; Probability plotting techniques; Hollander – Proschan and Deshpande tests for exponentiality; tests for HPP vs. NHPP with repairable systems.

References:

1. Barlow, R. E. and Proschan, F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
2. Lawless, J. F. (1982): Statistical Models and Methods of Life Time Data; John Wiley.
3. Nelson, W. (1982): Applied life Data Analysis; John Wiley.
4. Zacks, S.: Reliability Theory; Springer.
5. Bain, L. J. and Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

409: *Statistical Decision Theory*

UNIT - I

Decision problem and 2-person game, utility theory, loss functions, expected loss, decision rules (nonrandomized and randomized), decision principles (conditional Bayes, frequentist), inference problems as decision problems, optimal decision rules.

UNIT - II

Concept of admissibility and completeness, Bayes rules, admissibility of Bayes rules. Supporting and separating hyperplane theorems, minimax theorem for finite parameter space, minimax estimators of normal and poisson means, admissibility of minimax rules.

UNIT - III

Invariant decision rules – location parameter problems, invariance and minimaxity , admissibility of invariant rules, complete class theorem, complete and essentially complete classes in simple estimation and testing situations, estimation of a distribution function.

UNIT - IV

Sufficient statistics, essentially complete classes of rules based on sufficient statistics, complete sufficient statistics. Sequential decision rules, Bayes and minimax sequential decision rules, invariant sequential decision problems.

References:

1. Berger, J. O. (1985): Statistical Decision Theory and Bayesian Analysis, 2nd Edition. SpringerVerlag.
2. Ferguson, T. S. (1967): Mathematical Statistics – A Decision Theoretic Approach, Academic Pres.
3. Rohatgi, V. K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern, New Delhi.
4. Rao, C. R. (1973): Linear Statistical Inference and its Applications, Wiley Eastern.
5. Bernando, J. M. and Smith, A. F. M. Bayesian Theory, John Wiley and Sons.
6. Robert, C. P.: The Bayesian Choice: A Decision Theoretic Motivation, Springer.

410: ***Statistical Processes and Quality Control***

UNIT – I

Basic concepts of process monitoring ad control; process capability and process optimization. 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; Cu-Sum charts using V-masks and decision intervals; Economic design of $\bar{X}$- chart.

UNIT – II

Acceptance sampling plans for attributes inspection; single and double sampling plans and their properties; plans for inspection by variables for one-sided and two sided specification. Mil Std. and IS plans; continuous sampling plans of Dodge type and Wald-Wolfiwitz type and then properties. Sequential sampling plan and its properties; Bayesian sampling plans.

UNIT – III

Capability indices Cp, Cpk and Cpm; estimation, confidence intervals and tests of hypotheses relating to capability indices for normally distributed characteristics.

UNIT – IV

Use of design of experiments in Statistical Process Control; factorial experiments, fractional factorial designs; construction of such designs and analysis of data. Multivariate quality control; use of control ellipsoid and of utility functions.

References:

1. Montgomery, D. C. (1985): Introduction to Statistical Quality Control; Wiley.
2. Montgomery, D. C. (1985): Design and Analysis of Experiments; Wiley.
3. Ott, E. R. (1975): Process Quality Control; McGraw Hill
4. Phadke, M. S. (1989): Quality Engineering Through Robust Design; Prentice Hall.
5. Wetherill, G. B. (1977): Sampling Inspection and Quality Control; Halsted Press.
6. Wetherill, G. B. and Brown, D. W.: Statistical Process Control: Theory and Practice.

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411: *Survival Analysis*

UNIT – I

Concept of time, order and random censoring, likelihood in the distributions – exponential, gamma, Weibull, lognormal and Pareto distributions.

UNIT – II

Life tables, failure rate, mean residual life and their elementary properties. Ageing classes and their properties. Bathtub failure rate.

UNIT – III

Estimation of survival function – actuarial estimator, Kaplan – Meier estimator, estimation under the assumption of IFR/DFR. Comparsion between parameteric and non-parametric estimates. Total time on test.

UNIT – III

Two sample problem –log rank test and Gehan test. Semi-parametric regression for failure rate – Cox's proportional hazards model with one and several covariates. Likelihood Ratio (LR) test for the regression coefficient

References:

1. Cox, D. R. and Oakes, D. (1984): Analysis of Survival Data, Chapman and Hall, New York.
2. Gross A. j. and Clark, V. A. (1975): Survival Distribution: Reliability applications in the Biomedical Sciences, John Wiley and Sons.
3. Elandt – Johnson, R. E. Johnson N. L.: Survival Models and Data Analysis, John Wiley and Sons.
4. Miller, R. G. (1981): Survival Analysis (John Wiley).
5. Kalbfleisch J. D. and Prentice R. (1980): The Statistical Analysis of failure Time data, John Wiley.

305: *Practical*

Based on the contents of theory papers of electives.