M.A./M. Sc. (Statistics)

Department of Mathematics & Statistics, DDU Gorakhpur University, Gorakhpur

(effective from session 2015-2016)

The course of M.A/M.Sc. (Statistics) will be spread in two years - Previous and Final.

There will be two semesters in each year. There will be four theory papers and one practical in each semester.

Name of the Paper	Maximum Marks
Semester I	
1. Analysis, Measure Theory and Probability	50
2. Distribution Theory	50
3. Demography	50
4. Statistical Computing	50
Practical based on above papers.	50
Semester II	
1. Inference I	50
2. Stochastic Processes	50
3. Theory of Sample Surveys	50
4. Multivariate Analysis	50
Practical based on above papers.	50
Semester III	
1. Inference II	50
2.Linear Estimation and Design of Experiments	50
3. Operational Research I	50
4. Optional (Any one of the following)	50
(i) Statistical Process and Quality Control	
(ii) Applied Regression Analysis	
(iii) Quantitative Epidemiology	
(iv) Econometrics	
(v) Survival Analysis	
Practical based on above papers.	50
Semester IV	
1. Statistical Decision Theory	50
2. Bayesian Inference	50
3. Computer Intensive Statistical Methods	50
4. Optional (any one of the following)	50
(i) Reliability Theory	
(ii) Time Series Analysis	
(iii) Operations Research II	
(iv) Inference in stochastic Processes	
(v) Knowledge Discovery and Data Mining	
(vi) Actuarial Statistics	
Practical based on above papers.	50

M.A./M. Sc. (Statistics): Previous

(effective from session 2015-2016)

The M.A./ M.Sc. Previous (Statistics) examination will consist of two semesters, called first and second semesters. Their examinations will be held in the months of December and April respectively. In each of these semester examinations there will be four theory papers and a Practical based on the theory papers. Each paper will be of three hours' duration and of 50 maximum marks. There will be 9 questions in all in each theory paper including a compulsory question consisting of 6 parts of short answer type questions based on the contents of the whole course. The remaining 8 questions will be divided into two sections. Examinees will be required to answer 5 questions in all including the compulsory question and two questions from each section. Only 5 parts of the compulsory question will have to be answered. Besides the theory papers, there will be one practical examination of four hours' duration consisting of 50 marks (out of which 40 marks are assigned on the practical problems, 10 marks on practical record book and viva-voce).

First Semester

Compulsory Papers

Paper I	:	Analysis , Measure Theory and Probability
Paper II	:	Distribution Theory
PaperIII	:	Demography
Paper IV	:	Statistical Computing

Practical : based on above theory papers.

Second Semester

Compulsory Papers

Paper I	:	Inference I
Paper II	:	Stochastic Processes
Paper III	:	Theory of Sample Surveys
Paper IV	:	Multivariate Analysis

Practical : based on above theory papers.

M.A./M.Sc.(Statistics) First Semester
Paper I
Analysis , Measure Theory and Probability

Section A

Analysis: Open and closed sets in R and their properties. Compact sets in R. Bolzano-Wierstrass and Heine-Borel Theorem**.** Classes of sets, fields, sigma-fields, minimal sigma-field, Borel sigma-field in R_k, sequence of sets, lim sup and lim inf of a sequence of sets. Measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue and Lebesgue- Stieltjes measures on R_k.

Measurable functions, sequence of measurable functions, convergence in measure and convergence almost everywhere(and in measure). Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem. Radon-Nykodym theorem, product measure and Fubini's theorem.

(4 questions)

Section B

Random Variables, sequence of random variables, almost sure convergence, convergence in probability, Probability measure and probability space.

Borel- Cantelli Lemma, Independence. Weak law and strong law of large numbers for iid sequences, Definition and examples of Markov dependence, Exchangeable sequences, m-dependent sequences, stationary sequences.

Convergence in distribution, characteristic function, uniqueness theorem. Levy's continuity theorem (statement only), CLT for a sequence of independent random variables under Lindeberg's condition, CLT for non-iid random variables.

(4 questions)

Books recommended :

1. Ash, Robert. (1972). Real Analysis and Probability. Academic Press.
2. Billingsley, P. (1986) Probability and Measure. Wiley.
3. Dudley, R.M. (1989). Real Analysis and Probability, Wadsworth and Brooks/Cole.
4. Kingman, JFC and Taylor, S.J. (1966). Introduction to Measure and Probability, Cambridge University Press.
5. Loeve, M: Probability Theory, Von-Nostrand.
6. Royden: Real Anlysis.
7. Dudewieg. E. J. and Mishra. S.N. (1988): Modern Mathematical Statistics, Wiley.
8. Rohatgi. V.K. (1984) An Introduction to Probability Theory Mathematical Statistics, Wiley Eastern.
9. Rao. C.R. (1973): Linear Statistical Inference and Its application, 2/e, Wiley Eastern.
10. Kingman J. F. C and Taylor. S.J. (1966): Introduction of Measure and Probablity.
11. Pitman J. (1993): Probability, Narosa Publishing House.
12. Cramer H. (1946): Mathematical Methods of Statistics. Princeton.

M.A./M.Sc.(Statistics) First Semester
Paper II
Distribution Theory

Section A

Brief review of basic distribution theory. Joint, marginal and conditional p.m.fs. and p.d. fs. Standard discrete and continuous distributions.

Bivariate normal, Bivariate exponential, multivariate normal and multinomial distributions. Functions of random variables and their distributions using Jacobian of Transformation and other tools.

Compound, truncated and mixture distributions. Conditional expectation, correlation, multiple and partial correlation. Linear and multiple regression. Basic Markov, Holder, Jensen and Liapunov inequalities, Cr-inequalitiy.

(4 questions)

Section B

Approximating distributions. Delta method and its applications. 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.

Order statistics-their distributions and properties. Joint and marginal distributions of order statistics. Extreme Values and their asymptotic distributions (Statement only) with application. (4 questions)

Books recommended :

1. Dudewicz, E.J. and Mishra, S.N. (1988): Modern Mathematical Statistics, Wiley.
2. Rohatgi, V.K. (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern.
3. Rao, C.R. (1973): Linear Statistical Inference and its Applications, John Wiley and Sons, Inc..
4. Pitman, J. (1993): Probability, Narosa Publishing House.
5. Johnson, S. and Kotz, (1972): Distributions in Statistics, Vol. I, II and III, Houghton and Miffin.
6. Carmer H. (1946), Mathematical Methods of Statistics. Princeton.

M.A./M.Sc.(Statistics) First Semester
Paper- III
Demography

Section A

Source of demographic data. Scope and application of demography. Content error in demographic data. Balancing equations, Chandrasekharan-Deming formula to check completeness of registration data. Population composition and its measures. Dependence ratio.

Measures of fertility, cohort fertility, current family size , Age specific martial fertility rate, Birth order, Parity Progression Ratio. Length of generation, Population Growth Rate Doubling time.

(4 questions)

Section B

Measures of mortality, construction of Abridged life table by Grevilles method. Reed and Marrel method. Graduation of mortility curve-Makeham's model, Gompertz model. Infront mortality ratio.

Theory of migration, types and measures of migration, migration rates. Volume of migration and its estimation. Lee's model, Zipf's model, Stowffer's model for the migration process. Hamilton's rate, Migration component, migration streams.

(4 questions)

Books recommended :

1. Keyfitz, N. (1977) Applied Mathematical Demography John Wiley & Sons N.Y.
2. Cox P.R. (1976): Demography, Cambridge University Press.
3. Spiegelman, M. (1980) Introduction to Demography Harvard University Press
4. R. Ramakumar (1986): Technical Demography, Wiley Eastern limited.

M.A./M.Sc.(Statistics) First Semester
Paper -IV
Statistical Computing

Section A

Introduction to object-oriented programming, simple syntax, loops, functions, arrays, data frames and lists, input/output, workspace and files, scripts and packages.

Probability distributions: Computation of pdf, cdf, percentiles(tail areas) and relevant measures of location and dispersion of various univariate continuous probability distributions and associated graphics.

Elements of modern data analysis techniques: Tools for data analysis (numerical and visual summaries): descriptive statistics with graphics, representation of multivariate data and its visualization.

Exploratory data analysis: Empirical Distribution Function and its properties, quantile function, confidence interval of quantiles of order p, tolerance and convergence.

Stochastic simulation: Inverse-transform method, generation of random samples from various univariate probability distributions in R

(4 questions)

Section B

Linear Algebra : Solutions of matrix equations, generalized inverse, Idempotent matrices, Real quadratic forms, index and signature, triangular reduction of a positive definite matrix. Eigen values and vectors, algebraic and geometric multiplicity of eigen values, vector and matrix differentiation

Numerical integration of one variable function. Solution of non-linear equations: Roots extraction using different methods.

Numerical optimization : Maximum likelihood estimation : Solution of likelihood equations, Method of scoring, Newton-Raphson and other iterative procedures. Percentile method of estimation.

Matrix computation: addition, subtraction, transpose, multiplication, inverse, eigen values, eigen vectors and Spectral decomposition of a real symmetric matrix. singular value decomposition, Solution of system of linear equations.

(4 questions)

Books recommended :

1. Dalgaard, P.(2008). Introductory Statistics with R. Springer, 2nd edition.
2. Gentle, J.E.(2003). Random Number Generation and Monte Carlo Methods, Springer.
3. Rubinstein, R.Y. (1981). Simulation and the Monte Carlo Method, Wiley.
4. Venables, W. N. and Ripley, B. D. (2000). S Programming, Springer, New York.
5. Venables, W. N. and Ripley, B. D. (2002). Modern Applied Statistics with S, Fourth Edition, Springer, New York.

M.A./M.Sc.(Statistics) Second Semester
Paper – I
Inference -I

Section A

Parametric models, Point estimation. Test of Hypothesis and Interval estimation viewed as decision problems with given loss. Joint distribution of a sample and induced sampling distribution of a statistic. Likelihood Functions, Examples from standard discrete and continuous models (such as Bernoulli, Poisson, Negative Binomial, Normal, exponential, Gamma, Pareto etc.) Plotting Likelihood Functions for these models upto two parameters. Information in data about the parameters as variation in Likelihood, concept of no information, likelihood Equivalence, Minimal Sufficient Statistic, Exponential families and Pitman Families Statistics & subfields and conditional expectation Sufficiency, Neyman Factorizability Criterion. Invariance property of sufficiency under one-one transformation of sample space and parameter space. Fisher Information for one and several parameters models.

Methods of estimation **:** maximum likelihood method, methods of moments and percentiles, choice of estimators based on unbiased ness, minimum variance, mean squared error, minimum variance unbiased estimators, Rao – Blackwell Theorem, completeness, Lehmann – Scheffe theorems, necessary and sufficient conditions for MVUE, Cramer – Rao lower bound approach in multi-parameter case. Bhattacharya bound.

(4 questions)

Section B

Test 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 α tests, 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 a one parameter exponential family. Extension of these results to distribution with MLR property, non-existence of UMP test for simple null against two sided alternatives in one parameter exponential family. Definition of U-statistics and its properties as an estimator of its expectation, Introduction to Standard one sample and two sample non-parametric tests for location. Non-parametric confidence intervals for percentiles.

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 UPM test for one sided null against one sided alternative hypotheses.

(4 questions)

Books recommended :

1. Kale, B.K. (1999) A first Course on Parametric Inference, Narosa Publishing House.
2. Rohatgi V. (1988). An Introduction to Probability and Mathematical Statistics. Wiley Eastern Ltd. New Delhi (Student Edition).
3. Lehmann E.L. (1986)- (Latest) Theory of Point. Estimation (Student Edition)
4. Lehmann E.L. (1986). Testing Statistical hypotheses (Student Edition)
5. Rao, C.R. (1973) : Linear Statistical Inference and its applications, John Wiley and Sons, New York.
6. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics. Wiley Series Prob. Math. Stat., John Wiley and Sons, New York (International Student Edition)
7. Ferguson T.S. (1967). Mathematical Statistics. Academic Press.
8. Zacks, S. (1971). Theory of Statistical Inference, John Wiley and Sons, New York.
9. Zacks, S. (1981). Parametric Statistical Inference, Paragon Press.

M.A./M.Sc.(Statistics) Second Semester
Paper – II
Stochastic Processes

Section A

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;

Discrete state space & continuous time MC: Kolmogorov- Feller differential equations; Poisson process, birth and death process; Applications to queue and storage problems. Wiener process as a limit of random walk; first- passage time and other problems. (4 questions)

Section B

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 processes; Moving and auto regressive processes. Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size.

Martingale in discrete time, inequality, convergence and smoothing properties. (4 questions)

Books recommended :

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 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.

M.A./M.Sc.(Statistics) Second Semester
Paper – III
Theory of Sample Surveys

Section A

Basic finite population. Sampling techniques (SRSWR/SRSWOR, Stratified, Systematic) and related results on estimation of population mean/total. Allocation problem in Stratified sampling.

Ratio method of estimation, optimum properties of ratio estimator, unbiased ratio type estimators, ratio method of estimation in stratified sampling.

Regression method of estimation, regression estimators, regression estimators in stratified sampling.

Cluster sampling with equal and unequal size clusters.

Two-stage sampling: Two-stage sampling with equal number of second stage units, allocation of units at different stages.

(4 questions)

Section B

Two-stage sampling with unequal number of second stage units, allocation of units at different stages.

Sampling with varying probabilities : PPS sampling wr/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); Horvitz-Thompson estimator (HTE) of a finite population total/mean; expressions for V (HTE) and its unbiased estimator; issue of non-negative variance estimation, IPPS schemes of sampling due to Midzuno-Sen.

Randomized responses technique; Warner's model; related and questionnaire methods.

(4 questions)

Books recommended :

1. Chaudhuri, A. and Mukerjee, R. (1988): Randomized Response: Theory and Techniques. Marcel Dekker Inc.
2. Cochran, W.G.(1984): Sampling Techniques (3rd Edition, 1977). Wiley
3. Murthy, M.N.(1977): Sampling Theory & Methods. Statistical Publishing Society, Calcutta.
4. Sukhatme et al (1984): Sampling Theory of Surveys with Applications. Iowa State University Press & IARS.
5. Singh. D. and Chaudhary, F.S. (1986): Theory and Analysis of Sample Survey Designs. New Age International Publishers.
6. Chaudhuri. A. and J.W. E. Vos (1988): Unified Theory and Strategies of Survey Sampling. North-Holland.
7. Hedayat, A.S. and Sinha, B.K.(1991): Design and inference in finite population sampling. Wiley.
8. Mukhopadhyay, P. (1996): Inferential problems in survey sampling. New Age Internetional (P).
9. Des Raj and Chandak (1998): Sampling Theory. Narosa

M.A./M.Sc.(Statistics) Second Semester
Paper – IV
Multivariate Analysis

Section A

Multivariate normal distribution and its properties. Distribution of quadratic forms under normality. Multivariate Central limit theorem. Multivariate Characteristic function and Multivariate Cumulants. Sampling from a multivariate normal distribution and maximum likelihood function.

Wishart matrix- its distribution, characteristic function and reproductive property. Distribution of its maximum likelihood function of $\underline{\mu}$ and $\sum$. Box Cox transformations.

(4 questions)

Section B

Hotelling's T^2 statistic- definition, derivation of its pdf and properties.Likelihood ratio statistics Wilk's lambda.

Mahalnobis D^2. Use of T^2 and D^2 . The multivariate Behrens-Fisher problem.

Canonical Correlation and variables, properties and their estimation. Principal Component of multivariate observation and its Interpretation.

(4 questions)

Books recommended :

1. Anderson T.W. (1983): An Introduction its multination analysis. John Wiley & Sons.
2. Kshirsagar A.M. (1972): Multivariate Analysis. Marcel Dekker.
3. Giri N.C. (1977): Multivariate Statistical Inference, Academic Press.
4. Sharma, S. (1966): Applied Multivariate Techniques John Wiley & Sons.
5. Rao, C.R. (1973) : Linear Statistical Inference and its applications, John Wiley and Sons.

M.A./M. Sc. (Statistics): Final

(effective from session 2016-2017)

The M.A./ M.Sc. Final (Statistics) will consist of two semesters, called third and fourth semesters. Their examinations will be held in the months of December and April respectively. In third semester examinations there will be Three compulsory papers and one optional paper. In fourth semester examinations there will be three compulsory papers, one optional paper. Each paper will be of three hours' duration and of 50 maximum marks. There will be 9 questions in all in each theory paper including a compulsory question consisting of 6 parts of short answer type questions based on the contents of the whole course. The remaining 8 questions will be divided into two sections. Examinees will be required to answer 5 questions in all including the compulsory question and two questions from each section. Only 5 parts of the compulsory question will have to be answered. Besides the theory papers, there will be one practical examination of four hours' duration consisting of 50 marks (out of which 40 marks are assigned on the practical problems, 10 marks on practical record book and viva-voce).

Third Semester

Compulsory(Core) Papers

Paper I	:	Inference II
Paper II	:	Linear estimation and Design of Experiments
Paper III	:	Operations Research - I

Optional(Elective) Papers

Any one of the following papers will have to be opted:

Paper IV (a)	:	Statistical Process and Quality control
Paper IV (b)	:	Applied Regression Analysis
Paper IV (c)	:	Quantitative Epidemiology
Paper IV (d)	:	Econometrics
Paper IV (e)	:	Survival Analysis

Practical : based on above theory papers.

Fourth Semester

Compulsory(Core) Papers

Paper I	:	Statistical Decision Theory
Paper II	:	Bayesian Inference
Paper III	:	Computer-Intensive Statistical Methods

Optional (Elective) Papers

Any one of the following papers will have to be opted:

Paper IV (a)	:	Reliability Theory
Paper IV (b)	:	Time Series Analysis
Paper IV (c)	:	Operations Research - II
Paper IV (d)	:	Inference in Stochastic Processes
Paper IV (e)	:	Knowledge Discovery and Data Mining
Paper IV (f)	:	Actuarial Statistics

Practical : based on above theory papers .

M.A./ M. Sc. (Statistics) Third Semester
Paper I
Inference – II

Section A

Review of convergence in probability and convergence in distribution, Cramer and Slutsky's Theorems. Empirical distribution function

Consistent Estimation of real and vector valued parameter. Invariance of consistent estimator under continuous transformation, Consistency of estimators by method of moments. and 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.

Consistent Asymptotic Normal (CAN) estimator. Invariance of CAN estimator under differentiable transformation, CAN property to estimators obtained by moments and percentiles. CAN estimators obtained by moment and MLE method in one parameter exponential family, Extension to multiparameter exponential family. Examples of consistent but not asymptotically normal estimators from Pitman family Method of maximum likelihood. CAN estimators for one-parameter Cramer family, Cramer-Huzurbazar theorem. Solution of likelihood equations, Method of scoring, Newton-Raphson and other iterative procedures, Fisher Lower Bound to asymptotic variance, extension to multiparameter case (without proof). Multinomial distribution with cell probabilities depending on a parameter.

MLE in Pitman Family and Double Exponential distribution, MLE in censored and truncated distributions. (4 questions)

Section B

Wald's SPRT and its optimum properties.

Likelihood Ratio Test (LRT), Asymptotic distribution of LRT statistic, Wald Test, Rao's score test, Pearson's-test for Goodness of fit, Bartlett's Test for homogeneity of variances. Large Sample Tests and confidence intervals based on CAN estimators, Variance stabilizing transformation and large sample test. Consistency of Large Sample Test, Asymptotic power of large sample test. Glivenko Cantelli Theorem. Kolmogorov-Smironov test.

(4 questions)

Books recommended :

1. Kale, B.K. (1999): A First Course on parametric inference, Norasa, Publishing House.
2. Rohatgi V. K. (1988): An Introduction to Probability and Mathematical Statistics, Wiley Eastern Ltd. New Delhi
3. Lehmann, E.L. (1986): Testing Statistical Hypotheses, John Wiley & Sons.
4. Rao, C. R. (1973): Linear Statistical inferences, John Wiley & Sons.
5. Cramer, Herald (1945) : Mathematical Methods of Statistics, Asia Publications

M.A./ M. Sc. (Statistics) Third Semester
Paper II
Linear Inference and Design of Experiments

Section A

Linear Inference

Gauss-Markov set-up, Normal equations and Least squares estimates, Error and estimation spaces, variances and covariances of least squares estimates, estimation of error variance, estimation with correlated observations, least squares estimates with restriction on parameters, Sum of Squares

Tests of hypotheses for one and more than one linear parametric functions, confidence intervals and regions,

Design 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 estimable Linear Parametric Functions and testing of linear hypotheses); BIBD- recovery of interlock information;

Analysis of covariance

(4 questions)

Section B

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. Fractional replication for symmetric factorials. Split plot and split block experiments. (4 questions)

Books recommended:

1. Aloke Dey (1986): Theory of Block Designs, Wiley Eastern.
2. Angela Dean and Daniel Voss (1999): Design and Analysis of Experiments, Springer Verlag.
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, John Wiley& Sons, New York
8. Myers, R.H. (1971): Respnes Surface Methodology, Allyn & Bacon
9. Pearce, S.C. (1984): Design of Experiments, John Wiley& Sons, New Y
10. Rao, C.R. and Kleffe, J. (1988): Estimation of Variance Components and applications, North Holland.
11. Searle, S.R., Casella, G. and McCulloch, C.E.(1992): Variance Components, Wiley

M.A./ M. Sc. (Statistics) Third Semester
Paper III
Operational Research -I

Section A

Linear programming: Concept of duality in linear programming, duality theorem, dual simplex method, problem of degeneracy, degeneracy in transportation problem, Unbalanced transportation and assignment problem.

Sequencing and scheduling problem: Mathematical model, General assumption. Sequencing problem for n-job on 2 machine, n-job on 3 machine. problem with identical machine sequence for all jobs.

(4 questions)

Section B

Classical optimization techniques Lagrangian method, Kuhn-Tucker condition, related theorems. Generalized Lagrangian method to n- dimensional case. . Wolfe's modified method, , Beale's method for solving problem.

Information theory. Communication process, description of system, quantitative measure of information, Binary unit of information channel matrix, measure of uncertainty- entropy, properties of entropy functions and related theorem.

(4 questions)

Books recommended:

1. Hadley .G. (1964): Non-linear and Dynamic programming, Addison-Wesley.
2. Taha H.A. (1992): Operational Research; An Introduction, Macmillan.
3.Wagner H.M. (1973): Principal of D.R. with applications to Managerial decision, Printice Hall.
4. Swarup Kanti, P.K. Gupta (1985): Operational Research, Sultan Chand. & Sons.

M.A./ M. Sc. (Statistics) Third Semester
Paper - IV (a)
Statistical Process and Quality Control

Section A

Basis concept of process monitoring and 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 X-bar chart.

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.

(4 questions)

Section B

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

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

Multivariate quality control; use of control ellipsoid and of utility functions.

(4 questions)

Books recommended:

1. Montgomery, D.C.(1985) Introduction to Statistical Quality Control; Wiley
2. Montgomery, D.C.(1985) Design and Analysis of 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. (1995) Statistical Process Control, Theory and Practice; Chapman and Hall

M.A./ M. Sc. (Statistics) Third Semester
Paper - IV (b)
Applied Regression Analysis

Section A

Residulas and their analysis, Influential observations, Power transformations for dependent and independent variables.

Robust and L-1 regression, Estimation of prediction error by cross-validation and boot-strap. Non-linear regression models, Different methods of estimation (Least squares, Maximum Likelihood), Asymptotic properties of estimators.

(4 questions)

Section B

Generalized linear models, Analysis of binary and grouped data by using logistic models, Log-linear models.

Random and mixed effect models, Maximum likelihood, MINQUE and restricted maximum likelihood estimators of variance components, Best linear unbiased predictors (BLUP), Growth curves. (4 questions)

Books recommended:

1. Bates, D.M. and Watts, D.G. (1988). Nonlinear Regression Analysis and its Application, Wiley, New York.
2. Cook, R.D. and Weisberg, S. (1988). Residulas and Inference in Regression, Chapman and Hall, London.
3. Draper, N.R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., Wiley, New York
4. Efron, B. and Tibsirani, J.R. (1993). An Introduction to the Bootstrap, Chapman and Hall, New York
5. Kshirsagar, A.M. (1995). Growth Curves, Marcel and Dekker, New York.
6. McCullagh, P. and Nelder, J.A.(1989). Generalized Linear Models, 2nd Ed., Chapman and Hall, London.
7. Searles, S.R. (1987). Linear Models for Unbalanced Data, Wiley, New york.
8. Seber, G.A. and Wild, G.J. (1989). Nonlinear Regression, Wiley, New york.

M.A./ M. Sc. (Statistics) Third Semester
Paper - IV (c)
Quantitative Epidemiology

Section A

Introduction to modern epidemiology, principles of epidemiologic investigation, surveillance and disease monitoring in population. Epidemiology resources on the Web.

Epidemiologic measures: Organizing and presenting epidemiologic data, measures of disease frequency, renew of vital statistics and demography, measures of effected aerostation. Causation and causal inference.

(4 questions)

Section B

Design and analysis of epidemiologic studies: types of studies, case control studies, cohort studies, cross-over designs. regression models for the estimation of relative risk, meta analysis, quantitative methods in screening.

Special topics : epidemiology of infections and chronic diseases, environmental epidemiology, molecular and genetic epidemiology. (4 questions)

Books recommended:

1. K.J. Rothman and S, Greenland (1998) : Modern Epidemiology, Lippincott Roven press.
2. S. Selvin (1996) : Statistical Analysis of Epidemiology data, Oxford University Press.
3. D. Mc Neil (1996) : Epidemiological Research Methods Willy and Sons.

M.A./ M. Sc. (Statistics) Third Semester
Paper - IV (d)
Econometrics

Section A

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 observation and of equation.

Auto correlation, its consequences and tests. Theil BLUS procedure. Estimation and prediction. Multicollinearity problem, its implications and tools for handling the problem. Ridge regression.

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 analysis in econometrics.

(4 questions)

Section B

Simultaneous linear equations model, Examples, identification problem. Restrictions on structural parameters – rank and order conditions. Restrictions on variances and covariances.

Estimation in simultaneous equations model. Recursive systems. 2 SLS Estimators. Limited information estimators. K-class estimators, 3 SLS estimation. Full information maximum likehood method. Prediction and simultaneous confidence intervals. Monte Carlo studies and simulation.

(4 questions)

Books recommended:

1. Apte PG (1980); Text book of Econometrics. Tata McGraw Hill.
2. Carmer, J.S. (1971) Empirical Econometrics, North Holland
3. Gujarathi, D (1979): Basic Econometrics, McGraw Hill.
4. Intrulligator, MD (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 India.
7. Koutsoyiannis, A. (1979) : Theory of Econometrics, Macmillan Press.
8. Malinvaud, E (1966) : Statistical methods of Econometrics, North Holland.
9. Srivastava, V.K. nde Gles D.A.E. (1987) : Semingyureatd regresson eqations 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.

M.A./ M. Sc. (Statistics) Third Semester
Paper - IV (e)
Survival Analysis

Section A

Concepts of time, order and random Censoring, likelihood in these cases. Life distributions-Exponential Gamma, Weibull, Lognormal, Pareto, log-logistic and linear failure rate. Parametric inference for these distributions.

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

(4 questions)

Section B

Estimation of survival function-Actuarial Estimator, Kaplan-Meier Estimator, Estimation under the assumption of IFR/DFR. Tests of exponentiality against non-parametric classes-Total time on test. Hollander-Proschan test.

Two sample problem-Gehan test, Log rank test. Mantel-Haenszel test, Tarone -Ware tests.

Model Selection : AIC and BIC criterion

Semi-parametric regression for failure rate-Cox's proportional hazards model with one and several convariates. Competing risks model.

(4 questions)

Books recommended:

1. Cox, D.R., and Oakes, D.(1984). Analysis of Survival Data, Chapman and Hall, New York.
2. Elandt -Johnson, R.E., and Johnson, N.L. Survival Models and Data Analysis, John Wiley and Sons.
3. Kalbfleisch, J.D., and Prentice, R.L.(1980). The Statistical Analysis of Failure Time Data, John Wiley.
4. Klein, J. P.and Moeschberger, M. L. (1997). Survival Analysis, Springer-Verlag,, NewYork.
5. Lee, E.T., and Wang, T.W.(2003). Statistical Methods for Survival Data Analysis, 3rd ed., John Wiley and Sons.

M.A./ M. Sc. (Statistics) Fourth Semester
Paper – I
Statistical Decision Theory

Section A

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

Concepts 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.

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.

(4 questions)

Section B

Multivariate normal distribution, exponential family of distributions, 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, sequential tests of a simple hypothesis against a simple alternative. SPRT and stopping rule principle.

(4 questions)

Books recommended:

1. Berger, J.O. (1985). Statistical Decision Theory and Bayesian Analysis. 2nd Ed. Springer.
2. Ferguson, T.S. (1967). Mathematical Statistics-A Decision Theoretic Approach, Academic Press.

M.A./M.Sc.(Statistics) Fourth Semester
Paper – II
Bayesian Inference

Section A

Subjective interpretation of probability in terms of fair odds. Evaluation of (i) subjective probability of an event using a subjectively unbiased coin (ii) subjective prior distribution of a parameter. Bayes theorem and computation of the posterior distribution.

Natural Conjugate family of priors for a model. Hyper parameters of a prior from conjugate family. Conjugate families for (i) exponential family models, (ii) models admitting sufficient statistics of fixed dimension. Enlarging the natural conjugate family by (i) enlarging hyper parameter space (ii) mixtures from conjugate family, choosing an appropriate member of conjugate prior family. Non informative, improper and invariant priors. Jeffrey's invariant prior.

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 estimate in terms of the posterior risk.

(4 questions)

Section B

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.

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

Bayesian prediction problem.

Large sample approximations for the posterior distribution.

Bayesian calculations for non conjugate priors: (i) Importance sampling, (ii) Obtaining a large sample of parameter values from the posterior distribution using Acceptance-Rejection methods, Markov Chain Monte Carlo methods and other computer simulation methods.

(4 questions)

Books recommended:

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. DeGroot M.H. : Optimal Statistical Decisions. McGraw Hill.
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 Verlag.

M.A./M.Sc.(Statistics) Fourth Semester
Paper -III
Computer Intensive Statistical Methods

Section A

Stochastic simulation: Generation of random numbers and their applications. Pseudo Random numbers, linear congruential method. Inverse-transform method, composition method, acceptance-rejection method, transform methods, sums and mixtures, Monte-Carlo technique for generation of random samples from various univariate probability distributions.

Simulation from multivariate normal distribution, homogeneous and nonhomogeneous Poisson processes.

Monte Carlo integration: Simple Monte Carlo estimator and its standard error, variance and efficiency, variance reduction: antithetic variables and control variates, importance sampling for integration and variance in importance sampling.

Monte Carlo methods in inference**:** Monte Carlo methods for estimation, basic Monte Carlo estimation and standard error, estimation of MSE, estimating a confidence level. Simple problems on hypothesis tests.

Probability density estimation (univariate): Density estimation from histogram, Frequency polygon density estimate, The averaged shifted histogram, Kernal density estimation.

(4 questions)

Section B

Bootstrap methods: resampling paradigms, estimation of bias and standard errors, Confidence intervals: The basic, standard normal, percentile and bootstrap t-intervals, Better bootstrap confidence(BCa) intervals. Jackknife: The Jackknife estimation of bias and standard error, Jackknife after bootstrap. Bootstrapping in regression. Application: cross-validation.

Markov Chain Monte Carlo(MCMC) methods : Metropolis-Hastings, Gibbs and Metropolis within Gibbs algorithms for full conditional distributions, Issues in the implementation of MCMC. Convergence diagnostics: trace, ergodic mean, autocorrelation and Brook-Gelman-Rubin(BGR) plots. Output analysis: visual and numerical summary of MCMC samples.

ML estimation and asymptotic confidence intervals for exponential families.

Basic concept of Expectation-Maximization(EM) algorithm: applications to missing and incomplete data problems, mixture models.

(4 questions)

Books ecommended:

1. Efron, B. and Tibshirani, R.J.(1993): An Introduction to the Bootstrap, Chapman and Hall.
2. Fishman, G.S. (1996): Monte Carlo: Concepts, Algorithms, and Applications, SpringerVerlag.
3. McLachlan, G.J.,and Krishnan, T. The EM Algorithms and Extensions, John Wiley & Sons.
4. Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Method, John Wiley & Sons.
5. Tanner, M.A. (1996): Tools for Statistical Inference, Third edition, Springer Verlag.
6. Venables, W. N., and Ripley, B. D. (2000): S Programming, Springer, New York.
7. Venables, W. N., and Ripley, B. D. (2002): Modern Applied Statistics with S, , Springer Verlag, New York.

M.A./ M. Sc. (Statistics) Fourth Semester
Paper - IV (a)
Reliability Theory

Section A

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

Life distributions; reliability function; hazard rate; common life distributions- exponential, Weibull, gamma etc. Estimation of parameters and tests 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 or 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.

(4 questions)

Section B

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.

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

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

Basic ideas of accelerated life testing.

(4 questions)

Books recommend:

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

M.A./ M. Sc. (Statistics) Fourth Semester
Paper– IV(b)
Time Series Analysis

Section A

Time-series as discrete parameter stochastic process. Auto covariance and autocorrelation functions and their properties.

Exploratory Time Series Analysis, Tests for trend and Seasonality. Exponential and Moving Average Smoothing. Holt and Winters smoothing. Forecasting based on smoothing. Adaptive smoothing.

Detailed study of the stationary processes: (1) moving average (MA), (2) Auto regressive (AR), (3) ARMA and (4) AR integrated MA (ARIMA) models. Box- Jenkings models.

(4 questions)

Section B

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

Spectral analysis of weakly stationary process. Periodogram and correlogram analysis. Computations based on Fourier transform. Spectral decomposition of weakly AR process and representation as a one-sided MA process - necessary and sufficient conditions. Implication in prediction problems.

(4 questions)

Books recommended:

1. Box, G. E. P. and Jenkins, G.M. (1976): Time Series Analysis- Forecasting and Control, Holden-day, San Francisco.
2. Anderson, T.W. (1971): The Statistical Analysis of Time Series, John Wiley & Sons, N.Y.
3. Montgemory, D.C. and Johnson, L.A.(1977): Forecasting and Time Series Analysis, McGraw Hill.
4. Kendall, Sir Maurice and Ord, J.K. (1990): Time Series (Third Edition), Edward Arnold.
5. Brockwell, P.J. and Davis, R.A. Time Series: Theory and Methods (Second Edition). Springer
6. Fuller, W.A. (1976): Introduction to Statistical Time Series, John Wiley, N.Y.
7. Granger, C.W.J. and Newbold (1984): Forecasting Econometric Time Series, Third Edition, Academic Press.
8. Priestley, M.B. (1981): Spectral Analysis & Time Series, Charles Griffin, London.
9. Kendall, M.G. and Stuart A. (1966): The Advanced Theory of Statistics, Volume 3, Charles Griffin, London.
10. Bloomfield, P. (1976): Fourier Analysis of Time Series – An Introduction, John Wiley& Sons.
11. Granger, C.W.J. and Hatanka, M. (1964): Spectral Analysis of Economic Time Series, Princeton Univ. Press, N.J.
12. Koopmans, L.H. (1964): The Spectral Analysis of Time Series, Academic Press.
13. Nelson, C.R. (1973): Applied Time Series for Managerial Forecasting, Holden-Day.
14. Findley, D.F. (Ed.) (1981): Applied Time Series Analysis ll, Academic Press.

M.A./ M. Sc. (Statistics) Fourth Semester
Paper– IV(c)
Operations Research - II

Section A

Decision making in the face of Competition: Pure and mixed strategies. Existence of solution and uniqueness of value in zero-sum games. Finding solution in 2x2, 2xm, nx2 games. Nonzero-sum game. Co-operative and competitive games. Equilibrium solution and its existence in bimatrix games.

Inventory Management: Analytical structure of inventory problem. EOQ formula of Harris, its sensitive analysis. Multi item inventory subject to constraints. Model with random demand. Stochastic inventory model – a single period model with no setup cost having zero and non zero initial stock.

(4 questions)

Section B

Queuing Models: Specifications and effectiveness measures. Steady state solution of M/M/1 and M/M/c models with associated distributions of queue-length and waiting time. M/G/1 queue. Steady state solution of $M/E_K/1$ and $E_K/M/1$ queues.

Network Analysis: Introduction, arrow diagram representation. Critical path method. PERT technique. Calculation of probabilities of completing a project with specified period. Time-cost aspects in network analysis.

(4 questions)

Books recommended:

1. Saaty T.L.(1961) : Elements of Queueing Theory with Applications, MCGraw Hill.
2. Taha H.A. (1982) : Operational Research: An Introduction, Macmillan.
3. Hadley G. and Whiten T.M. (1983): Analysis r Inventory Systems : Prentice Hall.
4. Gross D. and Harris C.M. (1974) : Fundamental of Queueing theory, John Wiley & Sons.

M.A./ M. Sc. (Statistics) Fourth Semester
Paper– IV(d)
Inference in Stochastic Processes

Section A

Inference in Markov chains, estimation of transition probabilities, testing for order of a Markov chain, estimation of functions of transition probabilities, Parametric models and their goodness of fit.

Markov sequences, estimation of parameters based on likelihood and conditional least squares, auto-regressive series.

Statement of martingale strong law of large numbers and CLT for martingales, CAN property of the MLE from a general sequence of dependent random variables, Fisher information. Applications to Markov chains and sequences. (4questions)

Section B

Likelihood of Poisson and other Pure Jump Markov processes from first principle, CAN property of MLE's, testing for a Poisson Process, non-homogeneous processes, Analysis of parametric Pure Jump processes, Birth-Death-Immigration processes, testing goodness of fit of such models.

Diffusion processes and their likelihood, properties of estimators (without proof).

Branching processes. Inconsistency of MLE/moment estimators, Properties of estimators on the non-extinction path, Asymptotic distribution theory.

Elements of semi-parametric and non-parametric analysis, Theory and applications of optimal estimating functions, estimation of transition and stationary density, intensity function of a counting process. (4 questions)

Books recommended:

1. Billingsley, P.(1962): Statistical Inference for Markov chains, Chicago University Press, Chicago.
2. Basawa, l.V. and Prakasa Rao, B.L.S. (1980): Statistical Inference for Stochastic Processes, Academic Press, London.
3. Adke, S.R. and Manjunath, S.M.(1984): An introduction to Finite Markov Processes, Wiley Eastern, New Delhi.
4. Guttorp, P.(1991): Statistical Inference for Branching Processes, John Wiley & Sons.
5. Guttorp, P.(1995): Stochastic Modeling for Scientific Data, Springer Vrelag.
6. Bhat, B.R. (2000): Stochastic models: Analysis and Applications, New Age International Publishers, New Delhi.
7. Prakasa Rao B.L.S. and Bhat, B.R. (1996): Stochastic Processes and Statistical Inference, New Age International Publishers, New Delhi.

M.A./ M. Sc. (Statistics) Fourth Semester
Paper– IV(e)
Knowledge Discovery and Data Mining

Section A

Review of classification methods from multivariate analysis; classification and decision trees.

Clustering methods from both statistical and data mining viewpoints; vector quantization.

Unsupervised learning from univariate and multivariate data; dimension reduction and feature selection. (4 questions)

Section B

Supervised learning from moderate to high dimensional input spaces; artificial neural networks and extensions of regression models, regression trees.

Introduction to databases, including simple relational databases; data warehouses; and introduction to online analytical data processing.

Association rules and prediction; data attributes, applications to electronic commerce.

(4questions)

Book recommended:

1. A. Berson and S.J. Smith (1997). Data Warehousing, Data Mining, and OLAP. McGraw Hill.

M.A./ M. Sc. (Statistics) Fourth Semester
Paper IV (f)
Actuarial Statistics

Section A

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.

Principles of compound interest : Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Distribution of aggregate claims, compound Poisson distribution and its applications. Distribution of aggregate claims, compound Poisson distribution and its applications.

Life insurance : Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, differed insurance and varying benefit insurance, recursions, commutation functions.

(4 questions)

Section B

Life annuities : Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Net premiums : Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits.

Payment premiums, apportionable premiums, commutation functions, accumulation type benefits.

Net premium reserves: Continuous and discrete net premiums reserve, reserve on a semicontinuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

(4 questions)

Book recommended:

Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A., Nesbitt, C.J. (1996) : Actuarial Mathematics.