APPENDIX-2

SCHEME of INSTRUCTION
and
SYLLABI
for Proposed
M.Sc. STATISTICS
under
CHOICE BASED CREDIT SYSTEM (CBCS)

1. Scheme of Admission and Eligibility: Please refer to the Prospectus of the University.
2. Evaluation and Scheme of Examination: As per University rules and regulations.

M.Sc. STATISTICS

Syllabi for Semester I to IV:

Semester I :

Hard Core / Compulsory Paper:

Paper I: Real Analysis (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Elements of set theory, Sets in Euclidean space of k-dimensional R^k rectangles, neighbourhood, interior point and limit point, open and closed sets, Bolzano-Weierstrass theorem in R^2, Real valued functions continuity and uniform continuity.

Unit 2: Sequences and Series of constants- Limit superior, limit inferior and limit - properties. Cesaro sequences. Series of positive terms - Tests for convergence, divergence. Integral and Order tests and Kummers' test (statement only of all the tests)- Ratio and Raabe's tests as special cases of Kummers' test. Series of arbitrary terms - absolute and conditional convergence.

Unit 3: Sequences of functions-Uniform convergence and point wise convergence, Series of functions-uniform convergence-Weierstrass' M test. Power series and radius of convergence. Riemann-Stieltjes integration-continuous integrand and monotonic /differentiable integrator.

Unit 4: Functions of two variables-partial and directional derivatives. Maxima and minima of functions, maxima-minima under constraints(Lagrange's multipliers).

Unit 5: Parametric functions. Uniform convergence of improper integrals, Differentiation under integrals. Double integrals and repeated integrals. Change of variables under double integration-statement of the theorems without proof and solution of problems.

Books for reference:

Apostol, T.M. (1985): Mathematical Analysis, Narosa India Ltd.
Courant, R. and John, F. (1965): Introduction to Calculus and Analysis, Wiley.
Goldberg, R.R.(1970): Methods of Real Analysis, Oxford Publishing Co.
Khuri, A.T. (1993): Advanced Calculus with Applications in Statistics, John Wiley.
Rudin, W. (1976): Principles of Mathematical Analysis, Mc Graw Hill.
Shantinarayan (1950) : A course on Mathematical analysis, Sultan Chand and Co.

Hard Core / Compulsory Paper:

Paper II: Linear Algebra (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Fields, vector spates, subspaces; linear dependence and independence; basis and dimension of a vector space, finite dimensional vector spaces completion theorem. Examples of vector spaces over real and complex fields. Linear equations. Vector spaces with an inner product, Gram-Schmidt orthogonalization process. Orthonormal basis and orthogonal projection of a vector.

Unit 2: Linear transformations, algebra of matrices, row and column spaces of a matrix. Elementary matrices, determinants, rank and inverse of a matrix. null space and nullity; partitioned matrices; Kronecker product. Hermite canonical form, generalized inverse, Moore- Penrose Inverse, Idempotent matrices. Solutions of matrix equations.

Unit 3: Triangular reduction of a positive definite matrix. Characteristic roots and vectors, Cayley-Hamilton thoorem, minimal polynomial, similar matrices. Algebraic and geometric multiplicity of characteristic roots, spectral decomposition of a real symmetric matrix, reduction of a pair of real symmetric matrices, Hermitian matrices.

Unit 4: Real quadratic forms, reduction and classification of quadratic forms, index and signature. Singular values and singular decomposition, Jordan decomposition, extrema of quadratic forms. Vector and matrix differentiation.

Books for Reference:

Bellman, R. (1970): Introduction to Matrix Analysis, Second Edition, McGraw Hill.
Biswas, S. (1984): Topics in Algebra of Matrices, Academic Publications.
Graybill, F. A. (1983): Matrices with Applications in Statistics, Second Edition, Wadsworth..
Hadley, G. (1987): Linear algebra, Narosa.
Halmos, P. R. (1958): Finite Dimensional Vector Spaces, Second Edition, D. Van Nostrand Company.
Hoffman, K. and Kunze, R. (1971): Linear Algebra, Second Edition, Prentice Hall.
Rao, A. R. and Bhimasankaram, P.(1992): Linear Algebra, Tata McGraw Hill.
Rao, C. R (1973): Linear Statistical Inference and its Applications, Second Edition, Wiley.
Rao, C. R. and Mitra, S. K (1971): Genera1ized Inverse of Matrices and its Applications, Wiley.
Searle, S. R (1982): Matrix Algebra Useful for Statistics, Wiley.

Hard Core / Compulsory Paper:

Paper III: Probability Theory and Distributions – I (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Classes of sets, sequence of sets, limit superior and limit inferior of a sequence of sets, fields, sigma fields, minimal sigma field, Borel sigma field on the real line. Events, Sample space, Probability measure, Additive property,properties related to sequences of events, Independent events, Conditional probability and Bayes' theorem.

Unit 2: Measurable functions, random variables, sums, product and functions of random variables, sequence of random variables. Induced Probability measure, Distribution function Jordan decomposition theorem. Bivariate distributions-joint marginal and conditional distributions. Expectations and conditional Expectations.

Unit 3: Standard discrete and continuous univariate distribu1lons and their properties, Probability generating function and moment generating function. Bivariate normal and Multinomial distributions

Unit 4: Transformation technique. Sampling distributions, Chi-square, 1, F and Non-central chi-square and their properties. Bivariate Negative Binomial, Beta and Gamma distributions.

Unit 5: Markov, Chebyshev, Hoelder, Minkowski, Jensen and Liapunov inequalities. Relationship between tail of distributions and moments.

Books for Reference:

Cramer, H. (1946): Mathematical Methods of Statistics, Princeton.
Jolmson, S. and Kotz. (1972); Distributions in Statistics, Vols.I, II and III, Houghton and Miffin.
Mukhopadhyaya, P. (1996): Mathematical Statistics, Calcutta Publishing House.
Pitman, J. (1993): Probability, Narosa.
Rao, C. R (1973): Linear Statistical Inference and its Applications, Second Edition, Wiley Eastern.
Rohatgi, V. K (1984): An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern
Lukacs C (1970)' Characteristic functions, Griffin Publications.

Hard Core / Compulsory Paper:

Paper IV: Practicals based on Papers I – III (4 Credits – 8 hours of Theory teaching per week)

Soft Core Discipline Centric Paper:

Paper V: Statistical Computing (4 Credits – 3 hours of Theory teaching per week + 2 hours of Practicals per week)

Unit 1: Programming in C / R. (The purpose of this unit is to introduce programming with the eventual aim of developing skills required to .write statistical software. Should there be previous exposure to programming, this unit can be replaced with a more advanced unit in object oriented programming in C++ or Java. Topics should include Simple syntax, loops, pointers and arrays, functions, input/output, and linking to databases.

Unit 2: Numerical analysis and statistical applications. (The purpose of this unit is to apply programming skills in me1hods and algorithms useful in probability, statistics and data analysis. Topics should include numerical integration, root extraction, random number generation, Monte Carlo integration, matrix computations, drawing random samples : known univariate probability distributions -both discrete and continuous.

Unit 3: Analysis of interesting data sets using known techniques on a suitable statistical package such as R / MINITAB / SAS / SPSS / JMPIN; Topics should include graphics, descriptive statistics, representation of multivariate data, hypotheses testing, analysis of variance and linear regression.

Books for Reference:

Crawley, M. The R programming language, Shareware.
Keminghan, B. W. and Ritchie, D. M. (1988): The C Programming Language, Second Edition, Prentice Hall.
Press, W. H., Teukolsky, S. A., Vellering, W. T. and Flannery, B. P. (1993): Numerical recipes in C, Second Edition, Cambridge University Press.
Ryan, B. and Joiner, B. L. (2001):MINITAB Handbook, Fourth Edition, Duxbury.
Thisted, R. A. (1988): Elements of Statistical Computing. Chapman and Hall.

Soft Core Discipline Centric Paper:

Paper VI: Sample Surveys and Statistics for National Development (4 Credits – 3 hours of Theory + 2 hours of Practicals teaching per week)

A SAMPLE SURVEYS

Unit 1: Basic finite population sampling techniques (SRS WR/ WoR, stratified, systematic), related problems of population mean estimation, allocation problems in stratified sampling.

Unit 2: Unequal probability sampling: PPS WR / WoR methods (including Lahiri's scheme) and related estimators of a finite population mean (Hansen-Hurvitz and Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2).

Unit 3: Ratio and regression estimators based on SRS WoR method of sampling, two-stage sampling with equal. number of second stage units, double sampling, cluster sampling.

B. STATISTICS'FOR NATIONAL DEVELOPMENT

Unit 4: Economic development: growth ip. per capita income distributive justice. Indices of development, Human Development Index. Estimation of National Income - product approach, income approach and expenditure approach. Population growth in developing and developed countries. Population projection using Leslie matrix. Labour force projection.

Unit 5: Measuring inequality of incomes, Gini coefficient, Theil's measure. Poverty measurement-different issues, measures of incidence and intensity, combined measures, eg. Indices due to Kakwani, Sen. etc.

Books for Reference:

Choudhary, A and Mukherjee, R (1989): Randomized Response techniques, Marcel Decker.
Cochran, W. G. (1977): Sampling techniques, Third Edition, Wiley.
Des Raj and Chandok (1998): Sampling Theory, Narosa.
Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Calcutta.
Singh,D. and Choudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, New Age International.
Sukhatme et al. (1984): Sampling Theory of Surveys with Applications, Iowa State University Press.
C.S.O. (1980): National Accounts Statistics- Sources and Health.
Keyfitz, N. Mathematical Demography.
UNESCO: Principles of Vital Statistics Systems, Series M-12.
Sen, A(I997): Poverty and Inequality.

Second Semester:

Hard Core / Compulsory Paper:

Paper VII: Probability Theory and Distributions – II (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Lebesgue and Lebesgue Stieltjes measure on the real line. Integration of measurable functions with respect to measures. Monotone convergence theorem, Fatou's lemma and dominated convergence theorem.

Unit 2: Convergence in distribution, in Probability and with probability 1 and their implications. Slutsky's theorem. Weak law of large numbers- Ko1mogorov's generalized WLLN (proof of sufficient condition only), Khintchine's WLLN as special case, Chebyshev's WLLN.

Unit 3: Borel-Cantelli lemma, Kolmogorov's inequality. Strong law of large numbers - Kolmogorov's SLLN's for independent sequences and deduction for the ii.d. Case. Definitions and examples of Markov dependent, exchangeable and Stationary sequences. Characteristic function - properties, Inversion theorem (statement only and proof for density version), Uniqueness theorem, Continuity theorem (statement only). Central limit theorem- lindberg-Feller form (statement only). Deductions of Levy-Lindberg and Liapunov's forms

Unit 4: Order Statistics- their distributions and properties, Joint and marginal distributions. Extreme value distributions and their properties. Extreme value distributions as limit laws for the case of exponential, Normal, Uniform and Pereto.

Books for Reference:

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

Hard Core / Compulsory Paper:

Paper VIII: Inference – I (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Sufficiency, completeness, Uniformly minimum variance unbiased estimators, C-R inequalities, exponential class of densities and its properties, some special classes of distributions admitting complete sufficient statistics, extensions of these results to multi-parameter situation.

Unit 2: Test function, Neyman- Pearson lemma for test functions. Uniformly most powerful tests for one sided alternative for one parameter exponential class of densities and extension to the distributions having monotone likelihood ratio property.

Unit 3: Confidence Intervals, shortest expected length confidence intervals, relations with testing of hypotheses, uniformly most accurate confidence intervals.

Unit 4: Bayesian estimation, prior distributions, posterior distribution, loss function, principle of minimum expected posterior loss, quadratic and other common loss functions, conjugate prior distributions. Common examples. Bayesian HPD confidence intervals.

Books for Reference:

1. Kale, B.K. (2005). A First Course on Parametric Inference. Second Edition. Narosa.
2. Casella, G. and Berger, R. L. (2002). Statistical Inference. 2nd Edition, Duxbury Advanced series.
3. Dudewicz, E. J. and Mishra, S.N.(1988). Modern Mathematical Statistics, John Wiley.
4. Roussas, G. G. (1973). First Course in Mathematical Statistics, Addison Wesley.
5. Silvey, S. D. (1975). Statistical Inference, Chapman and Hall.
6. Wilks, S. S. (1962). Mathematical Statistics, John Wiley.
7. Lehmann, E. L. (1986). Testing of Statistical hypothesis, John Wiley.
8. Lehmann, E. L. (1988). Theory of Point Estimation, John Wiley.
9. Rohatgi, V. K. (1976). Introduction to theory of probability and Mathematical Statistics, John Wiley and Sons.
10. Berger, J.O. (1985). Statistical Decision Theory and Bayesian Analysis, Second Edition, Springer - Verlag.
11. Ferguson, T.S. (1967). Mathematical Statistics: A Decision Theoretic Approach. Academic Press.

Hard Core / Compulsory Paper:

Paper IX: Linear Models and Regression Analysis (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Gauss-Markov setup, normal equations and least squares estimates, error and estimation space, variance and covariance of least squares estimates, estimation of error variance, estimation with correlated observations, least squares estimates with restriction and parameters. simultaneous estimates of linear parame1ric functions.

Unit 2: Test of hypothesis for one and more than one parametric functions. Confidence intervals and regions, analysis of variance fable, power of F-test, multiple comparison test like Tukey and Scheffe, simultaneous confidence interval.

Unit 3: One way linear models when parameters are random and estimation of variance components. Simple linear regression, multiple regression - estimation, testing linear hypotheses, confidence interval, confidence region, prediction of new observations, prediction interval, fit of polynomials and use of orthogonal polynomial Introduction to non-linear models.

Unit 4: Model adequacy - residuals and their plot for examining the departure from assumptions such as fitness of the model, normality, homogeneity of variances and detection of outliers and remedies. Hat-matrix, leverages and detection of influential observations.

Unit 5: Multicollinearity, ridge and principal component regression. Validation of regression model: analysis of estimated coefficients and predicted values, collecting fresh data, data splitting. Subset selection of explanatory variables and Mallow's C_p statistic, all possible regressions, stepwise, forward and backward regressions.

Books for Reference:

Cook, RD. and Weisberg, S. (1982); Residual 'and Influence in Regression. Chapman and Hall, London.
Draper, N.R and Smith, H (1998): Applied Regression Analysis. Third Edition, WiIey, New York.
Gunst, R.F. and Mason, R.L. (1980) ; Regression Analysis and its Application - A Data Oriented Approach, Marcel-Dekker.
Montgomery,D.C, Peck, E.A. and Vining,G.G.(2003). Introduction to Linear Regression, John Wiley.
Rao, C. R (1913): Linear statistical Inference, Wiley Eastern.
Ryan,T.P.(1997). *Modern Regression Methods*, John Wiley, NY
Searle,S.R.(1971). *Linear Models*, John Wiley, NY.
Seber, G.A.F.(1997): *Linear Regression Analysis*. John Wiley, NY.
Seber, G.A.F. and Lee (2003): *Linear Regression Analysis*. 2/e John Wiley, NY
Weisberg, S. (1985): Applied Linear Regression, Wiley.

Hard Core / Compulsory Paper:
Paper X: Practicals based on Papers VI – VIII (4 Credits – 8 hours of Theory teaching per week)

Soft Core Discipline Centric Paper:

Paper XI: Project Work (4 Credits consisting of analysis of a Primary data and a Secondary data)

Third Semester:

Hard Core / Compulsory Paper:

Paper XII: Inference – II (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Consistency and asymptotic normality (CAN) of real and vector parameters. Invariance of consistency under continuous transformation. Invariance of CAN estimators under differentiable transformations, generation of CAN estimators using central limit theorem.

Unit 2: Method of moments, method of maximum likelihood, Special cases such as exponential class of densities and multinomial distribution, Cramer-Huzurbazar theorem, method of scoring.

Unit 3: Tests based on MLEs. Likelihood ratio tests, asymptotic distribution of log likelihood ratio, Wald Test, Score Test, locally most powerful tests. Applications to categorical data analysis, three dimensional contingency tables,

Unit 4: Pearson's chi-square test and LR test. Asymptotic comparison of tests. Asymptotic Relative Efficiency (Pitman's), asymptotic normality of posterior distributions.

Books for Reference:

1. Kale B.K. (2005). A First Course on Parametric Inference. Second Edition, Narosa.
2. Cramer, H.(1974). Mathematical Methods in Statistics, Princeton Univ. Press.
3. Rao, C. R.(1995). Linear Statistical Inference and its Applications, Wiley Eastern Ltd.
4. Silvey, S. D.(1975). Statistical Inference, Chapman- Hall.
5. Wilks, S.S.(1962). Mathematical Statistics, John Wiley.
6. Ferguson, T.S. (1996). A Course in Large Sample Theory, Chapman and Hall.

Hard Core / Compulsory Paper:

Paper XIII: Design and Analysis of Experiments (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Introduction to designed experiments; General block design and its information matrix, criteria for connectedness, balance and orthogonality; Intrablock analysis (estimability, best point estimates/interval estimates of estimable linear parametric functions and testing of linear hypotheses) of BIBD- recovery of interblock information.

Unit 2: Youden design - intrablock analysis. Analysis of covariance in a general Gauss-Markov model, applications to standard designs. Missing plot technique - general theory and applications.

Unit 3: Fixed, mixed and random effects models; Variance components estimation - study of various methods; General factorial experiments, factorial effects: best estimates and testing the significance of factorial effects; study of 2^M and 3^M factorial experiments in randomized blocks.

Unit 4: Complete and partial confounding. Fractional replication for symmetric factorials. Response surface experiments.

Books for Reference:

Aloke Dey (1986): Theory of Block Designs, Wiley Eastern.
Angela Dean and Daniel Voss (1999): Design and Analysis of Experiments, Springer.
Chakrabarti,M.C.(1962): Mathematics of Design and Analysis of Experiments, Asia.
Cocharan and Cox,D.R.(1957): Experimental Designs, John Wiley.
Das, M.N. and Giri, N.(1979): Design and Analysis of Experiments, Wiley Eastern.
Giri, N.(1986): Analysis of Variance, South Asian Publishers.
John, P.W.M.(1911): Statistical Design and Analysis of Experiments, Macmillan.
Joshi, D.D.(1987): Linear Estimation and Design of Experiments, Wiley Eastern.
Kempthorne,O. (1952); Design Analysis of Experiments, Wiley Eastern.
Montgomery,C.D.(1976): Design and Analysis of Experiments, Wiley, New York.
Mukhopadhyay,P.(1998): Applied Statistics, Books and Allied (P) Ltd.
Myers, R. H.(1971): Response Surface Methodology, Allyn and Bacon.
Pearce,.S.C.(1984): Design of Experiments, Wiley, New York .
Rao,C.R..andKleffu, J.(1988): Estimation of Variance Components and Applications, North Holland.
Searle, S. R., Casella, G. and McCullugh, C. E. (1992): Variance Components, Wiley.

Hard Core / Compulsory Paper:

Paper XIV: Multivariate Analysis (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Random sampling :limn multivariate normal distribution, maximum likelihood estimators of parameters, distribution of sample mean vector Wishart distribution (statement only) and its properties; distribution of sample generalized variance. Null distributions of sample correlation coefficient, partial. And multiple Correlation coefficients, distribution of sample regression coefficients. Application in testing and interval estimation.

Unit 2: Hotellings- T^2, Null distribution of Hotelling's T^2 statistic, Application in test on mean vectors for single and several multivariate normal populations.

Unit 3: Multivariate linear regression model, estimation of parameters, testing linear hypothesis about regression coefficients. Likelihood ratio test criterion. Multivariate analysis of variance of one and two way classified data.

Unit 4: Classification and discrimination procedures for discrimination into one of two multivariate normal populations. Sample discriminant function, tests associated ,with discriminant function, probabilities of misclassification and their estimation, classification into more than two mul1ivariate normal populations.

Unit 5: Principal components. Dimension reduction, canonical correlations and canonical variable - definition, use, estimation and computation.

Books for Reference:

Anderson, T.W. (1983): An. Introduction to Multivariate Statistical Analysis, Second Edition, Wiley.
Giri, N. C. (1977): Multivariate Statistical Inference, Academic Press.
Johnson and Wichern (1986) : Applied Multivariate Analysis, Wiley.
Kshirsagar,. A.M. (1972): .Multivariate Analysis, Marcel-Dekker. .
Morrison, D.F. (1976): Multivariate Statistical Methods, Second Edition, McGraw Hill.
Muirhead, R.J. (1982): Aspects of Multivariate Stalistica1 Theory, Wiley.

Rao, C. R. (1973). Linear Statistical Inference and its Applications, Second Edition, Wiley Eastern.
Seber, G.A.F. (1984) : Multivariate Observations, Wiley.
Sharma, S. (1996). Applied Multivariate Techniques, Wiley.
Srivastava, M.S. and Khattree, C. G. (1979). An Introduction to Multivariate Statistics, North Holland.

Hard Core / Compulsory Paper:

Paper XV: Practicals based on Papers XI – XIII (4 Credits – 8 hours of Theory teaching per week)

Soft Core Discipline Centric Paper:

Paper XVI: Reliability Analysis (4 Credits – 3 hours of Theory teaching + 2 hours of Practical teaching per week)

Unit 1: Life distributions : reliability function; hazard rate; common life distributions exponential, Weibull, Gamma, etc. Estimation of parameters and test in these models.

Unit 2: Notions of ageing : IFR, IFRA, NBU, DMRL, and NBUE classes and their duals; loss of memory property of the exponential distribution; closures of these classes under formation of coherent systems, convolutions and mixtures.

Unit 3: Univariate shock models and life distributions arising out of them; bivariate shock models; common bivariate exponential distributions and their properties.

Unit 4: Reliability estimation based on failure times in various censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation.

Unit 5: Maintenance and replacement policies; availability of repairable systems; modelling of a repairable system by a non-homogeneous Poisson process. Reliability growth models; probability plotting techniques; Hollander-Proschan' and Deshpande tests for exponentiality; test for HPP vs. NHPP with repairable systems. Basic ideas of accelerated life testing.

Books for Reference:

Barlow, R.E. and Proschan, F. (1985). Statistical Theory of Reliability.
Lawless, J.R (1982). StaJistica1 Models and Methods of Life Time Data.
Bain, L.J. and Engelhardt (1991). Statistical Analysis of Reliability and Life Testing Data.
Zacks, S. Reliability Theory.

Soft Core Discipline Centric Paper:

Paper XVII: Nonparametric and Semiparametric Methods (4 Credits – 3 hours of Theory + 2 hours of Practicals teaching per week)

Unit 1: Empirical distribution function, Glivenko-Cantelli theorem, Kolmogorov goodness of fit test. One sample U-statistics, Kernel and symmetric kernel, two sample U-statistics. asymptotic distribution of U-statistics. UMVUE property of U-statistics, asymptotic distribution of linear function of order statistics.

Unit 2: Rank tests, locally most powerful rank test, linear rank statistics and their distributional

properties under null hypothesis, Pitman's asymptotic relative efficiency.

Unit 3: One sample location problem, sign test and signed rank test, two sample Kolmogorov Smirnov tests. Two sample location and scale problems. Wilcoxon-Mann-Whitney test, normal score test, ARE of various test based linear rank statistics. Kruskal-Wallis K sample test.

Unit 4: Cox's proportional hazards model, rank test (partial likelihood) for regression coefficients, concepts of jackknifing method of Quenouille for reducing bias, bootstrap methods, confidence intervals.

Books for Reference:

Cox, D.R. and Oakes, D. (1983). Survival Analysis, Chapman and Hall.
Davison, A.C. and Hinkley, D.V. (1991). Boo-:strap methods and their application, Cambridge University Press.
Fraser, D.A.S. (1957). Nonparametric me1hods in Statistics, John Wiley.
Gibbons, J.D. (1985). Nonparametric Statistical Inference. Second Edition, Marcel-Dekker.
Hakek, J. and Sidak, Z. (1961): Theory of Rank Tests, Academic Press.
Puri, M.L and Sen, P.K (1971). Nonparametric methods in multivariate analysis, Wiley.
Randles, R.H and Wolfe, D.A. (1979). Introduction to the theory of nonparametric statistics, Wiley.

Soft Core Discipline Centric Paper:

Paper XVIII: Operations Research (4 Credits – 3 hours of Theory + 2 hours of Practical teaching per week)

Unit 1: Definition and scope of Operational research; phases in Operational research; models and their solutions; decision-making under uncertainty and risk, use of different criteria; sensitivity analysis.

Unit 2: LP Problem - Simplex method, Karmarkar's algorithm, duality theorem; transportation and assignment Problems; Wolfe's and Beale's algorithms for solving quadratic programming problems. Dynamic programming, Bellman's principle of optimality, general formulation, computational methods and applications of dynamic programming.

Unit 3: Analytical structure of inventory problems; EOQ formula of Ranis and its sensitivity analysis and extensions allowing quantity discounts and shortages. Multi-item inventory subject to constraints. Models with random demand, the static risk model. P and Q -systems with constant and random lead times, (t-S) po1icy.

Unit 4: Queueing .models - specifications; and effectiveness measures, steady-state solutions of M/M/I and M/M/C models with associated distributions of queue-length and waiting time. Queues with truncation Machine interference problem. M/G/I queue and Pollaczek-Khinchine result Steady - state solution of. M/E_k/I.

Unit 5: PERT and CPM Probability of project completion; PERT - crashing.

Books for Reference:

Churchman, C.W., Ackoff, R.L. and Amoff, E.L. (1957). Introduction to Operations Research.
Hillier, F.R and Leibennan, G (1962). Introduction to Operations Research
Kanti Swarup and Gupta, M.M. (1985); Operations Research.

Philips, D.T., Ravindran, A. and Solberg, J. Operations Research, Principles and Practice.
Taha, HA. (1982). Operational Research.

Soft Core Discipline Centric Paper:

Paper XIX: Statistical Process Control and Total Quality Management (4 Credits – 3 hours of Theory + 2 hours of Practical teaching per week)

Unit 1: Concept of quality. Quality characteristics. Control charts for variables and attributes. OC and ARL of control charts. Moving average (MA) and EWMA and CUSUM charts. Process control with auto correlated observations. Multivariate control charts.

Unit 2: Capability indices Cp, Cpk, and Cpm; estimation. confidence intervals and test of hypotheses.

Unit 3: Acceptance sampling plans for attribute inspection Single, Double. Multiple and Sequential sampling plans and their properties; Plants for inspection by variable for one-sided and two-sided specifications; continuous sampling plans - chain sampling plans TQM

Unit 4: TQM the seven QC tools. Quality costs. Six-sigma programme. Quality Systems - ISO 9000 standards series. Quality circles.

Books for Reference:
Johnson, N.L. and Kotz,S. (1993): Process capability indices, Chapman and Hall.
Montgomery; D. C. (1985): Statistical PrOi:eSS Control,Wiley.
Shridhara Bhat K. (2002): Total Quality Management Himalaya Publishing House.

Fourth Semester:

Hard Core / Compulsory Paper:

Paper XX: Stochastic Processes (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Introduction to stochastic processes (SP's); classification of SP's according to state space and time domain. Countable state Markov chains, (MC's). Chapman -Kolmogorov equations; calculation of n-step transition probability and its limit, Stationary distribution, classification of states; transient MC; Random walk., and gambler's ruin problem. Applications from social, biological and physical sciences.

Unit 2: Discrete state space continuous time MC: Kolmogorov- Feller differential equations; Poisson process, birth and death process; Applications to queues and storage problems. Wiener process as a limit of random walk first -passage time and other problems.
Unit 3: Renewal theory: Elementary renewal theorem and applications. Statement and uses of key renewal theorem; study of residual life time process. Stationary process: weakly stationary and strongly stationary. processes: Moving average and auto regressive processes.
Unit 4: Branching processes: Galton-Watson branching process, probability of ultimate extinction, distribution of population size. Martingale in discrete time, inequality, Convergence and smoothing properties. Statistical inference in MC and Markov processes.

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

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

Soft Core Discipline Centric Paper:

Paper XXI: Probability Measures on Metric Spaces (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Probability measures on metric spaces: Measures and integrals, tightness, (measure) determining class; Weak convergence of measures: properties of weak convergence and Portmanteau theorem, Convergence detennin1ng class.

Unit 2: Some special cases: Convergence of probability measures and convergence determining class in the Euclidean space, the circle, the space R^\infty, the product spaces etc.

Unit 3: Random clement of a metric space and its distribution, convergence in distribution of a sequence of random elements - various equivalent criteria for convergence; convergence in probability; weak convergence and mappings.

Unit 4: Relative compactness and Prohorov's theorem. Weak convergence and tightness in C[0, l]; Wiener measure. Weak convergence and tightness in D[O, 1]; Donsker's theorem.

Books for Reference:

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

Soft Core Discipline Centric Paper:

Paper XXII: Time Series Analysis (4 Credits – 3 hours of Theory + 2 hours of Practical teaching per week)

Unit 1: Time series as discrete parameter stochastic process, auto-covariance and auto-correlation functions and ,their properties.

Unit 2: Detailed study of the stationary processes: (i) moving average (MA), (ii) auto-regressive (AR), (iii) ARMA, and, (iv) AR integrated MA (ARIMA) models. Box-Jenkins models. Discussion (without proof) of estimation of mean, auto-covariance and auto-correlation functions under large sample theory.

Unit 3: Choice of AR and MA orders. Estimation of ARIMA model parameters. Forecasting. Residual analysis and diagnostic checking.

Unit 4: Spectral analysis of weakly stationary process, periodogram and correlogram analysis, computation based on Fourier transforms, Spectral decomposition of weakly AR process and representation as a one-sided MA process -necessary and sufficient conditions.

Unit 5: Implication of spectral decomposition in prediction problems. State space representation of time series. Kalman filter techniques.

Books for Reference:

Anderson. T.W. (1971). The Statistical Analysis of Time Series. Wiley.
Bloomfield, P. (2000). Fourier Analysis of Time Series: An Introduction. Second Edition, Wiley.
Box, G.E.P., Jenkins, G. W. and Reinsel, G.C. (1994). Time Series Analysis:Forecasting and Control Prentice Hall.
Box, G.E.P. and Jenkins, G.M (1976). Time Series Analysis - Forecasting and Control Holden-day, San Francisco.
Chatfield, C. Analysis of Time Series - Theory and Practice, Chapman and Hall.
Chow, C.G. (1985). Econometrics.. Mc Graw Hill.
Findley, D.F..ed., (1981). Applied Time Series Analysis II. Academic. Press.
Fuller, W.A. (1976). Introduction to Statistical Time series. Wiley.
Granger, C W.J. and Newbold (1984). Forecasting Econometric Time Series, Third Edition, Academic Press.
Granger, C.W.J. and Hatanka, M. (1964). Spectral Analysis of Economic Time Series, Princeton University Press.
Hannan. E.J. (1960). Time Series Analysis, Metheun, London.
Kendall, MG. (1974). Time Series, CnMles Griffin, London.
Kendall, MG> and Sroan, A. (1966). The Advanced Theory of Statistics, Vol. 3, Charles Griffin, London.
Koopmans, L.H. (1974). The Spectral Analysis of Time Series, Academic Press.
Montgomery, D.C. and Johnson, L.A (1977) Forecasting and Time Series Analysis, McGraw Hill.
Nelson, C.R (1973). Applied Time Series for managerial forecasting. Holden-day.
Priestly, MB. (1981). Spectral Analysis and Time Series. Griffin, London.

Soft Core Discipline Centric Paper:

Paper XXIII: Biostatistics (4 Credits – 3 hours of Theory + 2 hours of Practicals teaching per week)

Unit 1: Definition, agent, host and environment, mode of transmission; incubation period, spectrum of disease, herd immunity, classification of cause, of death, measures of mortality, studies of mortality. Measures of morbidity, I1lOIbidity surveys, issues and problems. Risk, cause and bias. Observational studies: retrospective, cross sectional and prospective studies.

Unit 2: Clinical trials: Methods of randomization, ethical issues, cross over trials. Sequential and group sequential trials. Interim analysis, multiple testing and stopping rules. Equivalence trials.
Unit 3: Clinical Epidemiology: Definition, reliability, validity, sensitivity, specificity, predictive values, likelihood ration test, selection and interpretation of diagnostic test. Deciding on the .best therapy.

Unit 4: ROC curves, multiple and parallel test. Screening for disease, critical appraisal, Meta analysis. Epidemiologic Models - Epidemometric studies- Deterministic epidemic models: Simple, General, Recurrent.

Unit 5: Time Series (Epidemic or others) Applications of Time series analysis in epidemiology - Simple descriptive techniques for detecting seasonal, Cyclical, secular and random variations

Books for Reference:

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

Soft Core Discipline Centric Paper:

Paper XXIV: Analysis of Categorical Data (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Categorical or count data, contingency table investigations associated with contingency table hypotheses, of independence in two-and three-way tables; analysis by fitting marginals log linear representation, internal' constraints problem, analysis of information, fitting strategies, algorithms to calculate quadratic approximations,confidence intervals.

Unit 2: Application, general linear hypotheses; external constraints problem; general formulation of MDI analysis, - single and K-sample cases, minimum modified chi-square estimations.

Unit 3: No linear interaction; general formularize in three-way table 2x2x2 table 4x2x2 table as examples.

Unit 4: Discrete classification models, full multinomial model and its variations.

Unit 5: Models for multivariate dichotomous responses- Bahadur model, loglinear and logit methods, Martin-Bradley model, KronmaI- Ott Tarter model, procedure leased on distributional distance. Variable -selection problem -m based on difference in discriminate score, Raiffas methods, Lachin's procedure, Kullback's divergence ,statistics procedure, Mixture of variables - Krazanowski's model and its analysis

Books for Reference:

Gokha1e, D.V. and Kullback,S. The information in contingency table,Marcel Dekker, 1979.
Goldstein, M. and Dillon, W.R Discrete Discriminant Analysis John Wiley, New York 1978.

Soft Core Discipline Centric Paper:

Paper XXV: Demography (4 Credits – 4 hours of Theory teaching per week)

Unit 1: Sources of Demographic data, coverage and content errors. Use of balancing equation and Chandrasekharan Deming formula, to check completeness of registration data. Use of Whipple's Myres Baachi's and UN indices.

Unit 2: Measures of fertility period and cohort measures. Use of birth order Statistics and child - Woman ratio. Brass technique to estimate current-fertility levels Estimation of TFR age patten! of fertility, differential fertility. Measures of reproduction and replacement.

Unit 3: Measures of mortality - standard death rates, neo-natal, perinatal death rates, maternal and infant mortality rates standardization of mortality rates. Construction of complete and abridged life tables. Expectation of life uses and application of life tables.

Unit 4: Rates and ratios of Migration Methods of estimating the volume of migration - Vital statistics method and survival ratio methods. Measurement of population growth. Population estimates and projections.

Unit 5: Stable and quasi stable population analysis. Statistical models for population growth. Mathematical models in mortality, fertility and human reproductive process.

Books for Reference:

Barclay. G. W. : Techniques of population analysis, John Wiley and Sons.
Spiegelman, H : Introduction to demography, Harvard University press.
Keyfitz, N. : Introduction to the mathematics of population; Addison -Wesley Publishing Co.,
Pollard, J.H. : Mathematical Models for the growth or human population, Cambridge University press.
Biswas, S.: Stochastic processes in Demography and applications, Wiley Eastern Ltd.
Chiang, C.L. : Introduction to Stochastic Processes m Biostatistics, John Wiley and Sons.
Ravikumar, R. Technical demography, Wiley Eastern Ltd.
Wolfenden, H.B. : Population Statistics and their compi1ation, American Actuarial Society.
United Nations Manuals: II, III, IV, VII.

Soft Core Discipline Centric Paper:

Paper XXVI: Survival Analysis (4 Credits – 3 hours of Theory + 2 hours of Practical teaching per week)

Unit 1: Concepts of Time, Order and Random Censoring. Life distributions - Exponential Gamma, Weibull, Lognormal, Pareto, Linear Failure rate. Parametric inference Point estimation, Confidence Intervals, Scores, tests based on LR , MLE

Unit 2: Life tables, Failure rate, mean residual life and their elementary properties. Ageing classes - IFR, IFRA, NBU, NBUE, HNBUE and their duals, Bathtub Failure rate.

Unit 3: Estimation of survival function - Actuarial Estimator, Kaplan - Meier Estimator, Estimation under the assumption of IFR/DFR.

Unit 4: Tests of exponentiality against non-parametric classes - Total time on test, Deshpande test. Two sample problem - Gehan Test, Log rank test. Mantel - Haenszel Test, Tarone - Ware tests.

Unit 5: Semi-parametric regression for failure rate - Cox's proportional hazards model with one and several covariates.

Books for Reference:

Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman and Hall, New York.
Gross, A. J. and Clark, V. A. (1975). Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
Elandt - Johnson, R.E., Johnson, N.L. (1980). Survival models and Data Analysis, John Wiley and Sons.
Miller, R.G. (1981). Survival Analysis, Wiley.
Zacks, S. Reliability.

Soft Core Discipline Centric Paper:

Paper XXVII: Computational Statistics (4 Credits – 2 hours of Theory + 4 hours of Practical teaching per week)

Unit 1: Statistical Simulations.

Unit 2: Stochastic simulations: generating random variables, simulating normal, gamma and beta random variables.

Unit 3: Comparison of algorithms to generate random variables. Generating random variables from failure rates. Simulating multivariate distributions, MCMC methods and Gibbs sampler, Simulating random fields, simulating stochastic processes.

Unit 4: Variance reduction techniques : importance sampling for integration, control variates and antithetic variables.

Unit 5: Simulating a non-homogeneous Poisson process. Optimization using Monte Carlo methods, simulated annealing for optimization. Solving differential equations by Monte Carlo methods.

Books for Reference:

Fishman, G.S. (1996) Monte Carlo: Concepts, Algorithms, and Applications. Springer.
Rubinstein, R.Y. (1981); Simulation and the Monte Carlo Method. Wiley.
Ripley B.D. (1987) Stochastic Simulations. Wiley.
Ross, S.M.(2002) Simulation, Third Edition, Academic.

Soft Core Discipline Centric Paper:

Paper XXVIII: Project Work (4 credits: One Primary data analysis and One Secondary data analysis OR One theoretical paper writing project in lieu of the latter)

Soft Core Elective for Non-Statistics students
Paper XXIX: Statistical Methods and Applications (4 Credits – 4 hours of Theory teaching per week)

DESCRIPTIVE STATISTICS:

Unit 1: Collection of data, Tabular and graphical representation of data. Attribute and Variable discrete and continuous. Analysis of data - Frequency distribution, histogram and Ogive.

Unit 2: Measures of location, dispersion/scale and skewness. Bivariate data - scatter diagram. Product moment correlation and linear regression, Spearman's rank correlation.

PROBABILITY THEORY:

Unit 3: Concepts of Probability, Standard Probability Distributions - Binomial Poisson, Geometric, Exponential normal t, F and Chi-square and properties.
SAMPLING:

Unit 4: Population and sample - simple random sampling. drawing random samples using random tables. Concepts of stratified random sampling. Standard error of sample mean and sample proportion.

STATISTICAL INFERENCE:

Unit 5: Testing for means, proportions and variance in one sample and two sample problems. Chi-square test for attributes. Analysis of variance - principles - one way and two way classification models

Books for Reference:
Goon A.M., Gupta, M.K. and Das Gupta B: Fundamental of Statistics Vol.1 and II. World Press Pvt. ltd., Calcutta.
Bhattacharya, G.K. and Johnson, R.A. Statistical concepts and methods. Wiley Eastern. Calcutta, Bombay and Delhi.
Levin, R.I. : Statistics for Management, Prentice Hall of India, New Delhi.
Hines, W. W. and Montgomery, D.C: Probability and Statistics -In Engineering and Management Science. Royal Press, New York.
Medhi J: Statistical Methods. Wiley Eastern Limited, New Delhi.

Soft Core Elective for Non-Statistics students

Paper XXX: Probability Theory and Mathematical Statistics (4 Credits – 4 hours of Theory teaching per week)

Unit 0: Review of set theory and calculus.

PROBABILITY THEORY:

Unit 1: Axiomatic Probability, Random Variables and distributions. Expectations and moments.

Unit 2: Standard discrete and continuous probability models. Sampling distributions. Modes of Convergence , WLLN, SLLN and CLT with applications (SLLN and CLT - statements only)

STATISTICAL METHODS:

Unit 3: Measures of central tendency and dispersion. Correlation and regression - curve fitting.

STATISTICAL INFERENCE:

Unit 4: Parameters and estimates. Methods of estimation - moment, maximum Likelihood Properties of estimators - Unbiasedness, MSE and consistency Interval. Estimation.

Unit 5: Testing of hypotheses - Basic concepts of testing, Neyman - Pearson lemma (Statement only) and examples Likelihood Ratio Tests - One sample and two sample problems.

Books for Reference:

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