DEPARTMENT OF MATHEMATICS AND STATISTICS

DDU GORAKHPUR UNIVERSITY, GORAKHPUR

Syllabus

of

STATISTICS

for
Two Years M.A. /M.Sc.
Programme

Semester Courses of M.A/M.Sc. Statistics Based on CBCS

The proposed curriculum is expected to provide the students a good overall knowledge of Statistics covering various aspects. They will not only be able to understand the important statistical techniques but also able to apply some commonly used statistical techniques to other fields. To familiarize students with computational techniques and software used in the statistical/data science arena. As a result, they can pursue their future career either in the core field or in the applied field of Statistics. Training in statistical computing will enhance their job opportunities and professional skills.

Programme Specific Outcomes (PSOs)

PS01. The proposed curriculum is expected to provide the students a good overall knowledge of Statistics covering various aspects. As a result, they will not only be able to understand the important statistical techniques but also able to apply some commonly used statistical techniques to other fields.

PS02. To enrich the ability of critical thinking, analytical and scientific reasoning to solve problems.

PS03. To develop understanding of Statistics and motivating the students to use Statistical techniques as a tool in the study of other scientific domains.

PS04. To encourage students for research studies in Statistics and related fields.

PS05. To provide students a wide variety of employment options as they can adopt research as a career or take up teaching jobs or can get employment in banking or can go for any other profession.

PS06. To inculcate problem solving skills, thinking and creativity through presentations, assignments and project work.

PS07. To help students in their preparation (personal counselling, books etc.) for competitive exams e.g. NET, GATE, etc.

PS08. To enable the students being life-long learners who are able to independently expand their Statistical expertise when needed.

Credit Based Semester Courses of
M.A./M. Sc.(Statistics)
Department of Mathematics & Statistics, DDU Gorakhpur University, Gorakhpur

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. The course is designed for 100 credits, equally divided into four semesters. There will be four theory papers (4 credits each), one practical of 8 credits and one seminar of 1 credit in each semester.

Name of the Paper	Maximum Marks
Semester I	
STAT 501 Analysis, Measure Theory and Probability	100(Theory:70+Internal Assessment :30)
STAT 502 Distribution Theory	100(Theory:70+Internal Assessment :30)
STAT 503 Demography	100(Theory:70+Internal Assessment :30)
STAT 504 Statistical Computing	100(Theory:70+Internal Assessment :30)
STAT 505 **Practical based on above papers.**	200 (Practical:140+Internal Assessment :60)
STAT 506 **Seminar**	25
Semester II	
STAT 507 Inference I	100(Theory:70+Internal Assessment :30)
STAT 508 Stochastic Processes	100(Theory:70+Internal Assessment :30)
STAT 509 Theory of Sample Surveys	100(Theory:70+Internal Assessment :30)
STAT 510 Multivariate Analysis	100(Theory:70+Internal Assessment :30)
STAT 511 **Practical based on above papers.**	200 (Practical:140+Internal Assessment :60)
STAT 512 **Seminar**	25
Semester III	
STAT 510 Inference II	100(Theory:70+Internal Assessment :30)
STAT 510 Linear Estimation and Design of Experiments	100(Theory:70+Internal Assessment :30)
STA- 303 Operational Research I	100(Theory:70+Internal Assessment :30)
4. Optional (Any one of the following)	100(Theory:70+Internal Assessment :30)
STAT 510 Statistical Process and Quality Control	
STAT 510 Applied Regression Analysis	
STAT 510 Quantitative Epidemiology	
STAT 510 Econometrics	
STAT 510 Survival Analysis	
STAT 510 **Practical based on above papers.**	(200 (Practical:140+Internal Assessment :60) **Seminar :** 25
Semester IV	
STAT 510 Statistical Decision Theory	100(Theory:70+Internal Assessment :30)
STAT 510 Bayesian Inference	100(Theory:70+Internal Assessment :30)
STAT 510 Computer Intensive Statistical Methods	100(Theory:70+Internal Assessment :30)
4. Optional (any one of the following)	100(Theory:70+Internal Assessment :30)
STAT 510 Reliability Theory	
STAT 510 Time Series Analysis	
STAT 510 Operations Research II	

STAT 510 Knowledge Discovery and Data Mining
STAT 510 Actuarial Statistics
STAT 510 Inference Discovery and Data Mininig
STAT 510 **Practical based on above papers.** 200 (Practical:140+Internal Assessment :60)
Seminar : 25

Credit Based Semester Courses of
M.A./M. Sc.(Statistics): Previous

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, one Practical and one Seminar based on the theory papers. Each theory paper will be of three hours' duration and of 70 maximum marks. There will be 9 questions in all in each theory paper including a compulsory question consisting of 4 parts of short answer type questions based on the contents of the whole course. The remaining 8 questions will be divided into four Units. Examinees will be required to answer 5 questions in all including the compulsory question and one question from each Unit. Only 3 parts of the compulsory question will have to be answered. All questions will carry equal marks, except stated otherwise. Besides the theory papers, there will be one practical examination of four hours' duration consisting of 140 marks (out of which 100 marks are assigned on the practical problems, 40 marks on practical record book and viva-voce). There will be internal assessment of 30 marks in each theory paper and of 60 marks for practical. There will be a Seminar of 25 marks based on theory papers in each semester.

First Semester

Compulsory Papers

STAT 501 Paper I	:	Analysis, Measure Theory and Probability
STAT 502 Paper II	:	Distribution Theory
STAT 503 Paper III	:	Demography
STAT 504 Paper IV	:	Statistical Computing

STAT 505 **Practical : based on above theory papers.**

STAT 506 **Seminar**

Second Semester

Compulsory Papers

STAT 507 Paper I	:	Inference I
STAT 508 Paper II	:	Stochastic Processes
STAT 509 Paper III	:	Theory of Sample Surveys
STAT 510 Paper IV	:	Multivariate Analysis

STAT 511 **Practical : based on above theory papers.**

STAT 512 **Seminar**

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

Paper I

Course Code	Course Title	Credits
STAT 501	Analysis, Measure Theory and Probability	4

Course Objective: The main purpose is to provide mathematical foundation for statistics courses to enhance their knowledge in Real Analysis and Measure Theory. To introduce Probability Theory under Axiomatic approach and develop further theory and concepts including the limit behaviours.

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : aware of the need and use of Real Analysis

CO 2 : Learn the concept of field, sigma field, probability space, probability measure.

CO 3 : understand independence of events and various inequalities.

CO 4 : Learn the concept of convergence of sequences of random variables.

CO 5 : Learn characteristic function, Borel Cantelli lemma, Kolmogrov 0-1 law, Law of Large Numbers, and CLT.

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.

Paper II

Course Code	Course Title	Credits
STAT 502	Distribution Theory	4

Course Objective: The aim of the course is to pay a special attention to applications of basic distribution theory, understanding basic distribution theory, Compound, truncated and mixture distributions with their applications.

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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

Course Outcomes:

After successful completion of this course, student shall be able to

CO 1 : Understand the concepts of basic distribution theory. Joint, marginal and conditional p.m.fs. and p.d.fs. Standard discrete and continuous distributions..

CO 2 : Gain the ability to understand the concepts of Compound, truncated and mixture distributions. Conditional expectation, correlation, multiple and partial correlation. Linear and multiple regression.

CO 3: Learn the concepts of Basic Markov, Holder, Jensen and Liapunov inequalities, Cr-inequalitiy.

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.

Paper- III

Course Code	Course Title	Credits
STAT 503	Demography	4

Course Objective : Tha main objective of the course is to describe current population trends, vital rates in terms of fertility, mortality, migration and population growth, which leads to production and planning of future population.

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course outcomes: After the completion of the course the student shall be able to

CO 1: Identify principal course of demographic data and their strengths and weaknesses.

CO 2: Discuss the demographic significance of age sex structure and their implications on society

CO 3: Develop analytical abilities of different demographic concept in quantitative term.

CO 4: In position to identify the components of population change and their effect and influence in human society

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.

Paper –IV

Course Code	Course Title	Credits
STAT 504	Statistical Computing	4

Course Objective: The objective of the course is to provide the understanding of linear algebra, matrix algebra and optimization. To enhance the programming skills and working knowledge of R software. The need and scope of modern data analysis techniques.

Unit-I

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.

Unit-II

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

Unit-III

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.

Unit-IV

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.

Course Outcomes: After the completion of the course, the student shall be able to

CO 1: understand linear algebra and matrix algebra.

CO 2: apply the modern data analysis techniques

CO 3 : computation of various quantities associated with probability distributions.

CO 4.: use R programming with some basic notions for developing their own simple programs and visualizing graphics in R.

CO 5: perform Computation using R programming.

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.

Course Code	Course Title	Credits
STAT 505	Practical	8
STAT 506	Seminar	1

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

Paper – I

Course Code	Course Title	Credits
STAT 507	Inference I	4

Course Objective: The main purpose is to make an individual understand basic theoretical knowledge about fundamental principles of statistical inference. To enhance the existing knowledge of Point Estimation and Testing of Hypothesis and introduce the concept of Interval Estimation.

Unit-I

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

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course Outcome: After the completion of the course, the student shall be able to

CO 1 : Learn different estimation techniques.
CO 2 : Learn properties of a good estimator.
CO 3 : Learn to develop estimators for estimating population parameter.
CO 4 : Learn basics of testing of hypothesis, calculation of type 1 and type 2 error.
CO 5 : Understand Cramer Rao inequality, Rao Blackwell theorem, Lehmann–Scheffe theorem.

CO 6 : Learn the concept of MVBUE, MVUE, UMVUE.
CO 7 : Methods of construction of MP test and UMP test using Neyman-Pearson lemma and MLR property.
CO 8 : Understand the concept of Interval Estimation and its construction.

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.

Paper – II

Course Code	Course Title	Credits
STAT 508	Stochastic Processes	4

Course Objective: The main objective of this course is to develop awareness for the use of stochastic models for representing random phenomena evolving in time such as inventory or queueing situations or stock prices behavior.

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

Branching process: Galton-Watson branching process, probability of ultimate extinction, distribution of population size.
Martingale in discrete time, inequality, convergence and smoothing properties.

Course Outcomes: After successful completion of this course, student shall be able to

CO 1: Use notions of long-time behaviour including transience, recurrence, and equilibrium in applied situations such as branching processes and random walk.

CO 2: Construct transition matrices for Markov dependent behaviour and summarize process information

CO 3: Use selected statistical distributions for modeling various phenomena.

CO 4: Understand the principles and objectives of model building based on Markov chains, Poisson processes and Brownian motion.

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.

Paper – III

Course Code	Course Title	Credits
STAT 509	Theory of Sample Surveys	4

Course Objective: The main objective is to provide the knowledge of concept of sample and population in statistics and also the various sampling schemes. Estimation of population parameters and their respective standard errors.

Unit-I

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.

Unit-II

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.

Unit-III

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);

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Learn the basic concept of sampling and related terminologies.
CO 2 : Understand various types of sampling schemes, with their advantages and disadvantages, and estimation of population parameters with their standard errors.
CO 3 : Learn the use of auxiliary information in the ratio and regression method of estimation.
CO 4 : Understand need of cluster and two stage sampling.
CO 5 : Learn sampling with varying probabilities
CO 6 : Understand some estimation techniques with special reference to non-response problems.

Books recommended :

1. Chaudhuri, A. and Mukerjee, R. (1988): Randomized Response: Theory and Techniques. Marcel Dekker Inc.
2. Cochran, W.G.(1984): Sampling Techniques (3^{rd} 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

Paper – IV

Course Code	Course Title	Credits
STAT 510	Multivariate Analysis	4

Course Objective: The main objective of the course is to simplified or reduced the dimension of data without sacrificing valuable information and make interpretation easier by canonical correlation, principal component, Hotelling T^2 and Mahalanobis D^2

Unit-I
Multivariate normal distribution and its properties. Distribution of quadratic forms under normality. Multivariate Central limit theorem. Multivariate Characteristic function and Multivariate Cumulants.

Unit-II
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.

Unit-III
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.

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

Course Outcomes: After completion of the course the student shall be able to

CO 1: Develop the interrelationships between two or more sample objects

CO 2: Analyse the interrelationship of the variables along the maen and variance and some other characteristic related to univariate analysis.

CO 3: Estimate and interpret the extent or amount of relationship among the variables.

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.

Course Code	Course Title	Credits
STAT 511	Practical	8
STAT 512	Seminar	1

Credit Based Semester Courses of
M.A./M. Sc.(Statistics): Final

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 70 maximum marks. There will be 9 questions in all in each theory paper including a compulsory question consisting of 4 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 3 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 140 marks (out of which 100 marks are assigned on the practical problems, 40 marks on practical record book and viva-voce).

Third Semester

Compulsory(Core) Papers

STAT 513 Paper I : Inference II
STAT 514 Paper II : Linear estimation and Design of Experiments
STAT 515 Paper III : Operations Research - I

Optional(Elective) Papers

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

STAT 516 Paper IV (a) : Statistical Process and Quality control
STAT 517 Paper IV (b) : Applied Regression Analysis
STAT 518 Paper IV (c) : Quantitative Epidemiology
STAT 519 Paper IV (d) : Econometrics
STAT 520 Paper IV (e) : Survival Analysis
STAT 521 : **Practical : based on above theory papers.**
STAT 522 : Seminar

Fourth Semester

Compulsory(Core) Papers

STAT 523 Paper I : Statistical Decision Theory
STAT 524 Paper II : Bayesian Inference
STAT 525 Paper III : Computer-Intensive Statistical Methods

Optional (Elective) Papers

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

STAT 526 Paper IV (a) : Reliability Theory
STAT 527 Paper IV (b) : Time Series Analysis
STAT 528 Paper IV (c) : Operations Research - II
STAT 529 Paper IV (d) : Knowledge Discovery and Data Mining
STAT 530 Paper IV (e) : Actuarial Statistics
STAT 531Paper IV (f) : Inference in Stochastic Processes
STAT 532 : Practical : based on above theory papers .
STAT 533 : Seminar

Third Semester
Compulsory (Core) Papers

Paper I

Course Code	Course Title	Credits
STAT 513	Inference II	4

Course Objective: To make aware the students of parametric, non-parametric and sequential estimation (point, as well as, interval) and testing (simple, as well as, composite hypotheses) procedures

Unit-I

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.

Unit-II

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. Wald's SPRT and its optimum properties.

Unit-III

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.

Unit-IV

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.

Course Outcomes: After successful completion of this course, student shall be able to

CO 1: Apply various parametric, non-parametric and sequential estimation techniques and testing procedures to deal with real life problems.

CO 2: Understand consistency, CAN estimator, MLE.

CO 3: Understand UMPU tests, SPRT, OC and ASN.

CO 4: Understand non-parametric methods, U-statistics, UMVU estimators.

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

Paper II

Course Code	Course Title	Credits
STAT514	Linear Estimation and Design of Experiments	4

Course Objective: This course provides the students the ability to understand Linear Estimation, the design and conduct experiments, as well as to analyze and interpret data.

Unit-I

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.

Unit-II

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

Unit-III

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

Unit-IV

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.

Course Outcomes: After successful completion of this course, student shall be able to

CO 1: Apply 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.

CO 2: Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance.

CO 3: Understand the concepts of balanced incomplete block designs, confounded factorial

experiments.

CO 4: Identify the effects of different factors and their interactions and analyse factorial experiments.

CO 5: Construct complete and partially confounded factorial designs and perform their analysis.

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

Paper III

Course Code	Course Title	Credits
STAT515	Operational Research I	4

Course Objective : Operations Research has wide application in our real life problems. Operations Research is an application oriented in mathematical sciences. It is very useful in Industry, Defence, Medical, Banking sector

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Outcomes of course: After completion of the course the student shall be able to

CO 1: Apply different operation research models in different sectors of research field.

CO 2: Develop research work in different interdisciplinary area related to real life problem.

CO 3: Get hired by most of the government and private companies as operations research scientists, since they require OR expert to get maximum output of minimum resources at minimum time.

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.

Optional (Elective) Papers

Paper - IV (a)

Course Code	Course Title	Credits
STAT516	Statistical Process and Quality Control	4

Course Objective: The main purpose of this paper is to introduce the most important field of applied statistics that contributes to quality control in almost all industries.

Unit-I

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.

Unit-II

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.

Unit-III

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

Unit-IV

Use of Design of Experiments in 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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Learn Process control and Product control.

CO 2 : Know and understand control charts and control limits.

CO 3 : Learn Sampling inspection plans for attributes and variables.

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

Paper - IV (b)

Course Code	Course Title	Credits
STAT517	Applied Regression Analysis	4

Course Objective: Regression modeling is the standard method for analysis of continuous response data. This course provides theoretical and practical training in statistical modeling with particular emphasis on linear and multiple regression.

Unit-I

Residuals 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.

Unit-II

Non-linear regression models, Different methods of estimation (Least squares, Maximum Likelihood), Asymptotic properties of estimators.

Unit-III

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

Unit-IV

Maximum likelihood, MINQUE and restricted maximum likelihood estimators of variance components, Best linear unbiased predictors (BLUP), Growth curves.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : learn how to derive simple and multiple linear regression models,

CO 2 : learn what assumptions underline the models,

CO 3 : learn how to test whether your data satisfy those assumptions and what can be done

when those assumptions are not met, and develop strategies for building best models.

CO 4 : learn how to create dummy variables and interpret their effects in multiple regression analysis; to build polynomial regression models and generalized linear models.

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, NewYork
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.

Paper - IV (c)

Course Code	Course Title	Credits
STAT518	Quantitative Epidemiology	4

Course Objective: The purpose of this course to introduce basic principles of epidemiology; measures of disease frequency; epidemiologic study designs: experimental and observational; bias; confounding; outbreak investigations; screening and causality. In addition, some special topics include epidemiology of infections and chronic diseases, environmental epidemiology, molecular and genetic epidemiology.

Unit-I

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

Unit-II

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.

Unit-III

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.

Unit-IV

Special topics : epidemiology of infections and chronic diseases, environmental epidemiology, molecular and genetic epidemiology.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Explain the role of epidemiology in the field of public health.

CO 2 : Describe and calculate epidemiological measures used to define and quantify health problems in and across defined populations.

CO 3 : Describe the range of epidemiologic study designs used to examine the health status of a population and be able to evaluate the strengths and limitations of each.

CO 4 : Identify and describe the impact of bias and confounding in epidemiologic studies

CO 5 : Understand the concepts of screening and testing in a range of health and other settings.

CO 6 : Understand the epidemiology of infections and chronic diseases, environmental epidemiology, molecular and genetic epidemiology.

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.

Paper - IV (d)

Course Code	Course Title	Credits
STAT519	Econometrics	4

Course Objective: The main objective is to introduce branch which is an integration of mathematics, statistics, and economics used to deal with econometric models.

Unit-I

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.

Unit-II

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.

Unit-III

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.

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

Unit-IV

Estimation in simultaneous equations model. Recursive systems. 2 SLS Estimators.

Limited information estimators. K-class estimators, 3 SLS estimation. Full information maximum likelihood method. Prediction and simultaneous confidence intervals. Monte Carlo studies and simulation.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Learn properties and problems of econometric models.
CO 2 : Understand the estimation and testing of hypothesis in econometric models.
CO 3 : Understand Simultaneous Equation Models

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.

Paper - IV (e)

Course Code	Course Title	Credits
STAT520	Survival Analysis	4

Course Objective: The main objective is to introduce different concepts and their interpretation in survival analysis.

Unit-I

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.

Unit-II

Life tables, failure rate, mean residual life and their elementary properties. Ageing classes-and their properties, bathtub failure rate.
Estimation of survival function-Actuarial Estimator, Kaplan-Meier Estimator,

Unit-III

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.

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Learn various statistical lifetime models.
CO 2 : Understand the concept involved in survival analysis.
CO 3 : Non-parametric estimation of survival data.
CO 4 : Learn model selection criterion.
CO 5 : Learn proportional hazards models.

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 andSons.
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.

Course Code	Course Title	Credits
STAT521	Practical	8

Course Code	Course Title	Credits
STAT522	Seminar	1

Fourth Semester
Compulsory (Core) Papers

Paper – I

Course Code	Course Title	Credits
STAT523	Statistical Decision Theory	4

Course Objective: The aim of this course is to provide a thorough theoretical grounding in Decision problems and 2-person game, utility theory, loss function, expected loss, decision rules, decision principles, inference problems as decision problems, optimal decision rules etc.

Unit-I

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.

Unit-II

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.

Unit-III

Multivariate normal distribution, exponential family of distributions, sufficient statistics, essentially complete classes of rules based on sufficient statistics, complete sufficient statistics.

Unit-IV

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.

Course Outcomes:

After successful completion of this course, student shall be able to

CO1: To analyse Decision problems and 2-person game, utility theory, loss function, expected loss, decision rules.

CO2: Concepts of admissibility and completeness. Bayes rules, admissibility of Bayes rules.

CO3: Understand how to use Multivariate normal distribution, exponential family of distributions, sufficient statistics.

CO4: Understand Sequential decision rules, Bayes and minimax sequential decision rules.

CO5: Work with sequential tests of a simple hypothesis against a simple alternative. SPRT and stopping rule principle.

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.

Paper – II

Course Code	Course Title	Credits
STAT524	Bayesian Inference	4

Course Objective: The objective of this course is to provide the understanding of the fundamentals of Bayesian inference including concept of subjectivity and priors by examining some simple Bayesian models and linear regression in a Bayesian framework.

Unit-I

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.

Unit-II

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.

Unit-III

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

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.

Unit-IV

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.

Course Outcomes:

After successful completion of this course, student shall be able to

CO1: Treat "evidence" as value of observations and prescribe methods to deal rationally with it.

CO2: Equip students with skills to carry out and interpret posterior and pre posterior data based modeling and analyses.

CO3: Compute probability that the theory in question could produce the observed data.

CO4: Examine some simple Bayesian models and linear regression in a Bayesian framework.

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.

Paper –III

Course Code	Course Title	Credits
STAT525	Computer Intensive Statistical Methods	4

Course Objective: The main objective of this paper is to make students understand computational intensive methods for doing statistical inference.

Unit-I

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.

Unit-II

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.

Unit-III

Probability density estimation (univariate): Density estimation from histogram, Frequency

polygon density estimate, The averaged shifted histogram, Kernal density estimation.
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.

Unit-IV

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 tomissing and incomplete data problems, mixture models.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Understand the basic ideas of Random Number Generation, Resampling and Simulation Methods.

CO 2 : apply computational methods, such as Monte Carlo simulations, the EM algorithm.

CO 3 : use Bayesian models to formulate and solve complex statistical problems.

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.

Optional (Elective) Papers

Paper - IV (a)

Course Code	Course Title	Credits
STAT526	Reliability Theory	4

Course Objective: The main objective is to introduce different concepts and their interpretation in reliability analysis.

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : Learn various statistical lifetime models.
CO 2 : Understand various classes and their interrelations.
CO 3 : Non-parametric estimation in lifetime data.
CO 4 : Learn accelerated life testing.

Books recommend:

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

Paper– IV(b)

Course Code	Course Title	Credits
STAT527	Time Series Analysis	4

Course Objective: The main purpose is to teach the time series modelling and the concept of forecasting and future planning

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : understand different time series models such as MA, AR, ARMA and ARIMA models.
CO 2 : learn of models for forecasting purpose.

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 – Verlag.
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.

Paper– IV(c)

Course Code	Course Title	Credits
STAT528	Operations Research II	4

Course Objectives: The objective of Operation Research is optimization that is to do things best under given circumstances. Operation Research has many applications in different valuable sections of the real life problems.

Unit-I

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.

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course Outcomes: After the completion of the course, the students shall be able to

CO 1. develop practical framework for conceiving social-economic situations among competing parties.

CO 2. in position to develop Inventory models in probabilistic environment describing the behavior of demand and supply.

CO 3. making optimum business decisions about resources needed to provide a service in a busy period.

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.

Paper– IV(d)

Course Code	Course Title	Credits
STAT529	Knowledge Discovery and data Mining	4

Course Objective: The main objective of this course is to introduce theoretical foundations of develop algorithms, and methods of deriving valuable insights from data which includes detection and identification of outliers and anomalies, understanding the sequential and temporal patterns.

Unit-I

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

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

Unit-II

Unsupervised learning from univariate and multivariate data; dimension reduction and feature selection.

Unit-III

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

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : learn to approach data mining as a process, by demonstrating
CO 2 : use of data mining to the decision-support level of organizations
CO 3 : learn to categorize and carefully differentiate between situations for
CO 4 : apply different data-mining techniques.
CO 5 : Identify appropriate methods to address a given problems with data mining methods such as frequent pattern mining, association, correlation, classification, prediction, and cluster and outlier analysis
CO 6 : to design and implement data-mining solutions for different applications
CO 7 : evaluate and compare different models used for Data Mining

Book recommended:

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

Unit-II

Unsupervised learning from univariate and multivariate data; dimension reduction and feature selection.

Unit-III

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

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : learn to approach data mining as a process, by demonstrating
CO 2 : use of data mining to the decision-support level of organizations
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CO 6 : to design and implement data-mining solutions for different applications
CO 7 : evaluate and compare different models used for Data Mining

Book recommended:

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

Paper IV (e)

Course Code	Course Title	Credits
STAT530	Actuarial Statistics	4

Course Objective: Actuarial Science is the discipline that applies mathematical and statistical methods to assess risk in the insurance and finance industries. In view of the uncertainties involved, probability theory, statistics and economic theories provide the foundation for developing and analysing actuarial models.

Unit-I

Utility theory, insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality.

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

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

Unit-II

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.

Unit-III

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.

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : modelling of individual and aggregate losses.

CO 2 : fitting of distributions to claims data, deductibles and retention limits, proportional and excess-of-loss reinsurance.

CO 3 : Risk models: models for individual claims and their sums.

CO 4 : finding distribution of aggregate claims, compound distributions and their applications,

CO 5 : finding of survival function, curate future lifetime, force of mortality.

CO 6 : handling problems on joint life and last survivor status and multiple decrement model.

CO 7 : mean and variance of various continuous and discrete payments for assurance and annuity contracts.

CO 8 : calculation of various payments from life tables using principle of equivalence, net premiums, prospective and retrospective provisions/reserves,

Book recommended:

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

Paper– IV(f)

Course Code	Course Title	Credits
STAT531	Inference in Stochastic Processes	4

Course Objective: The purpose of this course is to introduce the inferential procedures for Stochastic processes.

Unit-I

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.

Unit-II

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.

Unit-III

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).

Unit-IV

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.

Course Outcome: After successful completion of this course, student shall be able to

CO 1 : learn inferential procedures for Markov chain.
CO 2 : learn the concept of martingle and applications of Markov chain.
CO 3 : learn inferential procedures for Poisson and related processes.
CO 2 : learn the estimation procedure for branching processes..

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.

Course Code	Course Title	Credits
STAT532	Practical	8

Course Code	Course Title	Credits
STAT533	Seminar	1