DEPARTMENT OF STATISTICS

Scheme and Syllabus

M.Sc. (Statistics)

2016-18

CENTRAL UNIVERSITY OF HARYANA
JANT-PALI, MAHENDERGARH
HARYANA-123031
www.cuh.ac.in

Department of Statistics
Central University of Haryana
Mahendergarh, Haryana-123031

Scheme and Syllabus of M.Sc. Statistics
(CHOICE BASED CREDIT SYSTEM)

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Course Type

- Core Course (CC)
- Generic Elective Course (GEC)
- Discipline Centric Elective Course (DCEC)
- Skill Enhancement Elective Course (SEEC)

Total Credits: 96

Semester wise distribution of credits: 24 + 24 + 24 + 24.

SEMESTER I

Total credits: 24 (CC: 20, GEC: 4)

S. No.	Course Title	Course Code	Credits	Course Type
1.	Analysis and Linear Algebra	SPMS STAT 01 01 01 CC 4004	4	CC
2.	Statistical Methods	SPMS STAT 01 01 02 CC 4004	4	CC
3.	Probability Theory	SPMS STAT 01 01 03 CC 4004	4	CC
4.	Sampling Techniques	SPMS STAT 01 01 04 CC 4004	4	CC
5.	Practical	SPMS STAT 01 01 05 CC 0044	4	CC
6.	GEC (to be taken from other departments)		4	GEC

Courses for other departments (GEC):

S. No.	Course Title	Course Code	Credits	Course Type
1.	Interdisciplinary Statistics	SPMS STAT 01 01 01 GEC 3014	4	GEC
2.	Programming in R	SPMS STAT 01 01 02 GEC 3014	4	GEC

SEMESTER II

Total credits: 24 (CC: 16, DCEC: 4, GEC: 4)

S. No.	Course Title	Course Code	Credits	Course Type
1.	Distribution Theory	SPMS STAT 01 02 01 CC 4004	4	CC
2.	Statistical Inference-I	SPMS STAT 01 02 02 CC 4004	4	CC
3.	Linear Models and Regression Analysis	SPMS STAT 01 02 03 CC 4004	4	CC
4.	Practical	SPMS STAT 01 02 04 CC 0044	4	CC
5.	DCEC		4	DCEC
6.	GEC (to be taken from other departments)		4	GEC

Courses for students of M.Sc. (Statistics) only (DCEC):

S. No.	Course Title	Course Code	Credits	Course Type
1.	Reliability Theory	SPMS STAT 01 02 01 DCEC 4004	4	DCEC
2.	Survival Analysis	SPMS STAT 01 02 02 DCEC 4004	4	DCEC
3.	Operations Research and Queuing Theory	SPMS STAT 01 02 03 DCEC 4004	4	DCEC
4.	Statistical Computing using C	SPMS STAT 01 02 04 DCEC 4004	4	DCEC

Courses for other departments (GEC):

S. No.	Course Title	Course Code	Credits	Course Type
1.	Applied Statistics	SPMS STAT 01 02 01 GEC 3014	4	GEC
2.	Operations Research	SPMS STAT 01 02 02 GEC 4004	4	GEC

SEMESTER III

Total credits: 24 (CC: 16, DCEC: 8)

S. No.	Course Title	Course Code	Credits	Course Type
1.	Design of Experiments	SPMS STAT 01 03 01 CC 4004	4	CC
2.	Econometrics	SPMS STAT 01 03 02 CC 4004	4	CC
3.	Statistical Inference-II	SPMS STAT 01 03 03 CC 4004	4	CC
4.	Practical	SPMS STAT 01 03 04 CC 0044	4	CC
5.	DCEC		4	DCEC
6.	DCEC		4	DCEC

Courses for students of M.Sc. (Statistics) only (DCEC):

S. No.	Course Title	Course Code	Credits	Course Type
1.	Time Series and Statistical Quality Control	SPMS STAT 01 03 01 DCEC 4004	4	DCEC
2.	Biostatistics	SPMS STAT 01 03 02 DCEC 4004	4	DCEC
3.	Stochastic Process	SPMS STAT 01 03 03 DCEC 4004	4	DCEC
4.	Demography and Vital Statistics	SPMS STAT 01 03 04 DCEC 4004	4	DCEC
5.	Order Statistics	SPMS STAT 01 03 05 DCEC 4004	4	DCEC
6.	Simultaneous Inference	SPMS STAT 01 03 06 DCEC 4004	4	DCEC

SEMESTER IV

Total credits: 24 (CC: 12, DCEC: 4, Dissertation: 8)

S. No.	Course Title	Course Code	Credits	Course Type
1.	Multivariate Analysis	SPMS STAT 01 04 01 CC 4004	4	CC
2.	Bayesian Inference	SPMS STAT 01 04 02 CC 4004	4	CC
3.	Practical	SPMS STAT 01 04 03 CC 0044	4	CC
4.	Dissertation/Project	SPMS STAT 01 04 01 PROJ 0008	8	Dissertation
5.	DCEC		4	DCEC

Courses for students of M.Sc. (Statistics) only (DCEC):

S. No.	Course Title	Course Code	Credits	Course Type
1.	Generalized Linear Models	SPMS STAT 01 04 01 DCEC 4004	4	DCEC
2.	Categorical Data Analysis	SPMS STAT 01 04 02 DCEC 4004	4	DCEC
3.	Decision Theory and Sequential Analysis	SPMS STAT 01 04 03 DCEC 4004	4	DCEC
4.	Statistical Simulation And Computation	SPMS STAT 01 04 04 DCEC 4004	4	DCEC
5.	Actuarial Statistics	SPMS STAT 01 04 05 DCEC 4004	4	DCEC

ANALYSIS AND LINEAR ALGEBRA

(SPMS STAT 01 01 01 CC 4004)

Objectives: This course provides help to understand the mathematical concept of convergence and its mathematical formalisms. Students will be able to use some fundamental theorems of mathematical analysis. Students will have knowledge of the special character of functions of a complex variable and their properties. The students also will be well equipped to apply these techniques in many major Statistics courses like Linear Inference, Multivariate Analysis during this course.

UNIT I

Recap of elements of set theory, introduction to real numbers, open and closed intervals (rectangles), compact sets, Bolzano-Weirstrass theorem. Sequences and series, their convergence, real valued functions, continuous functions, Uniform continuity, Uniform convergence. Differentiation, maxima-minima of functions.

UNIT II

Complex numbers, Analytic function, Cauchy fundamental theorem, Cauchy integral theorem, contour integrations.

UNIT III

Determinant and trace, rank, ranks of product of two matrices, Elementary matrices and Echelon forms. Partitioned matrices: addition, multiplication and inverse. Cayley Hamilton Theorem, diagonalization, generalized inverse: Definition and its computation.

UNIT IV

Definite and semi definite quadratic forms, index and signatures, simultaneous diagonalization of symmetric matrices (equivalent quadratic forms), extrema of quadratic forms. Vector spaces, sub-spaces, linear dependence and independence, orthogonalization process, orthonormal basis.

Suggested Readings:

1. Apostol, T.M. (2002): Mathematical Analysis, 2nd Edition. Narosa Publishing House.
2. Bartle, R.G. (1976). Elements of Real Analysis, 2nd Edition. John Wiley & Sons.
3. Conway, J.B. (2000). Functions of One Complex Variable, Springer-Verlag.
4. Rudin, Walter (2013): Principles of Mathematical Analysis, 3rd Edition. McGraw Hill.
5. Graybill, F.A. (2002): Matrices with Applications in Statistics, 2nd Edition. Wadsworth International Group.
6. Rao, C.R. and Mitra, S.K. (1971): Generalized Inverse of Matrices and its Application, John Wiley and Sons Inc.
7. Biswas, S. (2012): A Textbook of Matrix Algebra, 3rd Edition. PHI Learning.

STATISTICAL METHODS

(SPMS STAT 01 01 02 CC 4004)

Objectives: The objective of the course is to make the students conversant with various techniques used in summarization and analysis of data. The focus will be both on theoretical as well as practical approach using commonly used statistical softwares.

UNIT I

Measures of central tendency, dispersion (including box and whisker plot), skewness and kurtosis. Data on two attributes, independence and association of attributes in 2x2 contingency tables. Linear regression and correlation (Karl Pearson's and Spearman's) and residual plots. Multiple and partial correlations. Basic concepts of Binomial, Poisson, Geometric, Normal, Exponential distributions along with applications.

UNIT II

Concept of population, parameter, random sample, statistic and sampling distribution. Expectations and standard errors. Sampling distributions of sample mean and sample variance from a normal distribution and their independence. Sampling distributions of chi-square, t and F distributions and their relations.

UNIT III

Statistical hypotheses, type I and type II errors, level of significance, concept of p-value. Tests of significance for the parameters of normal distribution (one sample and two sample problems) and the relevant confidence intervals. Chi-square test of goodness of fit and independence of attributes. Test of significance for correlation coefficient $(\rho = 0 \text{ and } \rho = \rho_0)$.

UNIT IV

Time series and its components. Trend determination by mathematical curve fitting and by moving average methods. Measurement of seasonal variations by ratio to moving average and ratio to trend methods.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. I & II, World Press.
2. Daniel, W.W. and Cross, C. L. (2013): Biostatistics: A Foundation for Analysis in the Health Sciences. Wiley and Sons, Inc., New York.
3. Stuart, A. and Ord Keith (1994): Kendall's Advanced Theory of Statistics: Distribution Theory. Wiley and Sons, Inc., New York.

PROBABILITY THEORY

(SPMS STAT 01 01 03 CC 4004)

Objectives: This course will lay the foundation to probability theory and statistical modelling of outcomes of real life random experiments through various statistical distributions.

UNIT I

Classes of sets, field, sigma field, minimal sigma field, Borel field, sequence of sets, limits of a sequence of sets, measure, probability measure, Integration with respect to measure. Random experiment, outcomes, sample space, events, various definitions of probability, laws of total and compound probability. Boole's inequality. Conditional probability, independence of events. Bayes Theorem.

UNIT II

Random variable, probability mass function, probability density function, cumulative distribution function. Expectation of a random variable, properties of expectation, conditional expectation and its properties. Bivariate distributions and the joint probability distribution. Independence of random variables. Marginal and conditional distributions.

UNIT III

Moment generating function, probability generating function, cumulant generating function, characteristic function and their properties. Inversion, continuity and uniqueness theorems.

UNIT IV

Convergence in probability, almost sure convergence, convergence in distribution and their relationships. Chebyshev's inequality, weak law of large numbers (WLLN), strong law of large numbers (SLLN), central limit theorems.

Suggested Readings:

1. Rohatgi V.K. and Saleh A.K. Md.E. (2015): An Introduction to Probability and Statistics, 3rd Edition, Wiley India (P.) Ltd.
2. Bhat, B.R. (2004). Modern Probability Theory, 3rd Edition., New Age International, New Delhi.
3. Rao, B. L. S. Prakasa (2009): A First Course in Probability and Statistics. World Scientific.
4. Casella, G. and Berger, R. L. (2007): Statistical Inference, 2nd Edition, Cengage Learning.
5. Hogg, R. V., McKean, J. and Craig, A. T. (2013): Introduction to Mathematical Statistics, 7th Edition, Pearson Education.
6. Mukhopadhyay, P. (2015): Mathematical Statistics, New Central Book Agency, New Delhi.

SAMPLING TECHNIQUES

(SPMS STAT 01 01 04 CC 4004)

Objectives: The objective of this course is to acquaint the students about: (i) the need & merits of sampling over census and (ii) the implementation of various sampling schemes along with their merits, demerits and comparisons in appropriate practical situations, (iii) role of various statistical organizations in national development.

UNIT I

Introduction to usual notations used in sampling. Basic finite population sampling techniques: Simple random sampling, simple random sampling without replacement (SRSWOR), simple random sampling with replacement (SRSWR), stratified random sampling, systematic sampling and related results on estimation of population mean/total. Relative precision of different sampling techniques. Allocation problem in stratified sampling.

UNIT II

Ratio and regression estimators based on SRSWOR method of sampling. Two-stage sampling with equal size of first stage units. Double sampling for ratio and regression methods of estimation. Cluster sampling – equal clusters.

UNIT III

Unequal probability sampling: PPS WR/WOR methods [cumulative total and Lahiri's methods] and related estimators of a finite population mean [Horwitz -Thompson, Yates-Grundy, Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2].

UNIT IV

National sample survey organization (NSSO) and role of various statistical organizations in national development. Scope and contents of population census in India. Review of national income and their estimates.

Suggested Readings:

1. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Ashok, C. (1984): Sampling Theory of Surveys with Applications, Iowa State University Press and I.A.S.R.I., PUSA, New Delhi.
2. Singh, D. and Chaudhary, F.S. (2016): Theory and Analysis of Sample Survey Designs, Ist Edition. New Age International Publishers.
3. Cocharn, W.G. (2008): Sampling Techniques, 3rd Edition, Wiley India.
4. Mukhopadhyay, P. (2009): Theory and Methods of Survey Sampling, 2nd Edition, Prentice Hall of India.
5. Murthy, M.N. (1967): Sampling: Theory and Methods, Statistical Publishing Society, Kolkata.

PRACTICAL

(SPMS STAT 01 01 05 CC 0044)

Practicals based on Statistical Methods (SPMS STAT 01 01 02 CC 4004) and Sampling Techniques (SPMS STAT 01 01 04 CC 4004).

INTERDISCIPLINARY STATISTICS

(SPMS STAT 01 01 01 GEC 3014)

Objectives: The objective of this course is to define a variety of basic statistical terms and concepts, solve fundamental statistical problems, understanding of statistical fundamentals to interpret data.

UNIT I

Introduction to Statistical Analysis: Mean, median, mode, range, mean deviation, variance, standard deviation, coefficient of variation, skewness, kurtosis.

UNIT II

Random Variables and Probability Distribution: Random experiment, outcomes, sample space, classical definition of probability, random variable, probability mass function, probability density function, cumulative distribution function, mathematical expectation, Variance, Binomial, Poisson, Geometric, Exponential, Normal distributions.

UNIT III

Hypothesis Testing: Null hypothesis, alternative hypothesis, type I error, type II error, level of significance, p-value and power of test. Tests for mean based on normal distribution – one sample t-test, two-sample t-test, paired-sample t-test. Tests for variance based on normal distribution – one sample and two-sample problem. One-Way and Two-Way analysis of variance (ANOVA) techniques.

UNIT IV

Linear Regression and Correlation: Karl Pearson's correlation coefficient, Spearman's rank correlation coefficient, principle of least square, lines of regression, simple linear regression, coefficient of determination.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. I & II, World Press.
2. Walpole, R.E., Myers, R.H., Myers, S.L. and Ye, K. E (2012): Probability and Statistics for Engineers and Scientists, Pearson Education.
3. Daniel, W.W. and Cross, C. L. (2012): Biostatistics: A Foundation for Analysis in the Health sciences, 10th Edition, Wiley Global Education.

PROGRAMMING IN R

(SPMS STAT 01 01 02 GEC 3014)

Objectives: The objective of the course is to enhance the programming skills and working knowledge of available numerical and statistical softwares.

UNIT I

Data types in R: numeric/character/logical; real/integer/complex, creation of new variables, vectors, matrices, dataframes, lists, accessing elements of a vector or matrix, import and export of files, for loop, repeat loop, while loop, if command, if else command.

UNIT II

Graphics in R: the plot command, histogram, bar-plot, box-plot, points, lines, segments, arrows, inserting mathematical symbols in a plot, pie diagram, customization of plot setting, graphical parameters, adding text, saving to a file, adding a legend.

UNIT III

Vector matrix operations: matrix operations such as addition, subtraction, multiplication, rank, eigenvalues, matrix inverse, generalized inverse, solution of linear equations.

UNIT IV

Basic statistics using R: measures of central tendency and dispersion. Covariance, correlation, regression, some discrete and continuous probability distributions, one and two sample z and t tests, Bartlett's test, F test for equality of variances, Chi-square tests, confidence intervals, one-way and two-way ANOVA, random number generation.

Suggested Readings:

1. Michael J. C. (2015): Statistics: An Introduction Using R, First Edition John Wiley and Sons.
2. Dalgaard, P. (2008): Introductory Statistics with R, 2nd Edition, Springer.
3. Zuur, A. F., Leno, E. N. and Meesters, E. H. W. G. (2009): A Beginner's Guide to R, Springer.
4. Maindonald, J. H. and Braun, J. (2010): Data Analysis and Graphics Using R, 3rd Edition, Cambridge University Press.
5. Spector, P. (2008): Data Manipulation with R, Springer, New York.
6. Rizzo, M. L. (2008): Statistical Computing with R, Chapman & Hall/CRC.
7. Murdoch, D. J. and Braun, J. (2016): A First Course in Statistical Programming with R, 2nd Edition, Cambridge University Press, Cambridge.

DISTRIBUTION THEORY

(SPMS STAT 01 02 01 CC 4004)

Objective: The main objective of the course is to provide the detailed knowledge of the characterization of all the useful discrete and continuous distributions.

UNIT I

Bernoulli, Binomial, Poisson, Geometric, Negative Binomial, Multinomial, Hypergeometric, Discrete Uniform distribution. Their means, variances, modes, moment generating functions, probability generating functions and characteristic functions. The various important properties with their proofs related to these distributions.

UNIT II

Continuous Uniform, Exponential, Gamma, Normal, Beta, Cauchy, Laplace, Weibull, Pareto, Lognormal, Logistic with their properties including proofs. Their means, variances, moment generating functions and characteristic functions.

UNIT III

Compound, truncated and mixture distributions. Non-central chi-square, t and F distributions with their properties.

UNIT IV

Bivariate normal distribution with its applications and important properties. Standard bivariate normal distribution. Development of the formula of recurrence relation for moments and other important related problems to this distribution.

Suggested Readings:

1. Rohatgi V.K and Saleh A.K. Md.E. (2015): An Introduction to Probability and Statistics, 3rd Edition, Wiley India (P) Ltd.
2. Mukhopadhyay, P. (2015): Mathematical Statistics. Books & Allied (P) Ltd.
3. Casella, G. and Berger, R. L. (2007): Statistical Inference, 2nd Edition. Cengage Learning.
4. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. I, World Press.
5. Mood, A., Grabill, F. and Boes, D. (2001): Introduction to the Theory of Statistics, McGraw Hill Education.
6. Mukhopadhyay, P. (1998): Theory and Methods of Survey Sampling, Prentice Hall of India.

7. Jhonson, N.L., Kemp, A.W. and Kotz, S. (2008): Univariate Discrete Distributions, 3rd Edition, Wiley-Blackwell.

8. Jhonson, N.L., Kotz, S., Balakrishnan, N. (1994): Continuous Univariate Distributions, Wiley-Blackwell.

STATISTICAL INFERENCE-I

(SPMS STAT 01 02 02 CC 4004)

Objective: The objective of estimation theory is to arrive at an estimator that exhibits optimality. The estimator takes observed data as an input and produces an estimate of the parameters. Also, to provide a systematic account of Neyman Pearson theory of testing and closely related theory of point estimation and confidence sets, together with their applications.

UNIT I

Criteria of a good estimator- unbiasedness, sufficiency, consistency, efficiency. Minimal sufficient statistic. Exponential and Pitman families of distributions. Complete statistic, ancillary statistic, Rao-Blackwell theorem, Lehmann-Scheffe theorem, Cramer-Rao lower bound approach to obtain minimum variance unbiased estimator (MVUE).

UNIT II

Method of moments, Maximum likelihood estimation, minimum chi-square estimation, method of scoring, CAN & BAN estimators.

Concepts of critical regions, test functions, two kinds of errors, size function, power function, level of significance. Neyman - Pearson Lemma, Most Powerful (MP), Uniformly Most Powerful (UMP) and Uniformly Most Powerful Unbiased (UMPU) tests.

UNIT III

Likelihood ratio test (LRT) with its asymptotic distribution, Similar tests with Neyman structure, Basu' s theorem. Construction of similar and UMPU tests through Neyman structure. Wald's SPRT with prescribed errors of two types.

UNIT IV

Interval estimation: Confidence interval, confidence level, construction of confidence intervals using pivotal, shortest expected length confidence interval, uniformly most accurate one sided confidence interval and its relation to UMP test for one sided null against one sided alternative hypotheses. Tests of hypotheses and interval estimation viewed as decision problems with given loss functions.

Suggested Readings:

1. Rohatgi, V.K and Saleh, A.K. Md.E. (2015): An Introduction to Probability and Statistics, 3rd Edition, Wiley India (P) Ltd.

2. Lehmann, E.L. and Casella, G. (2003): Theory of Point Estimation, 2nd Edition, Springer.

3. Lehmann, E.L. and Romano, J.P. (2008): Testing Statistical Hypotheses, 3rd Edition, Springer.

4. Casella, G. and Berger, R. L. (2007): Statistical Inference, 2nd Edition, Cengage Learning.

5. Mood, A., Grabill, F. and Boes, D. (2001): Introduction to the Theory of Statistics, McGraw Hill Education.

6. Mukhopadhyay, P. (2015): Mathematical Statistics. Books & Allied (P) Ltd.

7. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2013): An Outline of Statistical Theory, Volume II. 3rd Edition, World Press (P) Ltd.

8. Kale, B.K. (2005): A First Course on Parametric Inference, 2nd Edition, Alpha Science International Ltd.

LINEAR MODELS AND REGRESSION ANALYSIS

(SPMS STAT 01 02 03 CC 4004)

Objective: The students will get familiar with the need of modeling random responses using independent predictors through linear and logistic (for binary responses) models in real life situations. Least square estimation of parameters of these models will be discussed along with their statistical significance.

UNIT I

Linear Estimation: Gauss-Markov linear Models, Estimable functions, Error and Estimation Spaces, Best Linear Unbiased Estimator (BLUE), Least square estimator, Normal equations, Gauss-Markov theorem, generalized inverse of matrix and solution of Normal equations.

UNIT II

Variance and covariance of Least square estimators, applications of fundamental theorems of least squares. Test of Linear Hypothesis: One way and two way classifications. Fixed, random and mixed effect models (two way classifications only), variance components.

UNIT III

Regression Analysis: Simple and multiple regression, model validation, detection of outliers, remedies and tests about regression coefficients. Quadratic and cubic regression models including their geometrical interpretation, idea of nonlinear regression. Orthogonal Polynomials and their fitting. Analysis of covariance.

UNIT IV

Models for binary response –logistic regression model. Bartlett test for testing of homogeneity of variances.

Suggested Readings:

1. Rao, C.R. (2009): Linear Statistical Inference and its Applications, 2nd Edition, Wiley India (P) Ltd.
2. Draper, N.R. and Smith, H. (2011): Applied Regression Analysis, 3rd Edition, Wiley India (P) Ltd.
3. Kleinbaum, D.G. and Klein, M. (2010): Logistic Regression – A Self Learning Text, 3rd Edition, Springer Verlag.
4. Graybill, F.A. and Blackwell, D. (2013): An Introduction to Linear Statistical Models, Vol. – I, Literary Licensing.
5. Rencher, A.C. and Schaalage, G.B. (2008): Linear Models in Statistics, 2nd Edition, Wiley-Blackwell.
6. Weisberg, S. (2013): Applied Linear Regression, 4th Edition, Wiley-Blackwell.
7. Bowerman, B.L. and O'Connel, R.T. (2000): Linear Statistical Models: An Applied Approach, 2nd Edition, Duxbury Press.

PRACTICAL

(SPMS STAT 01 02 04 CC 0044)

Practicals based on Distribution Theory (SPMS STAT 01 02 01 CC 4004), Statistical Inference-I (SPMS STAT 01 02 02 CC 4004) and Linear Models and Regression Analysis (SPMS STAT 01 02 03 CC 4004).

RELIABILITY THEORY

(SPMS STAT 01 02 01 DCEC 4004)

Objective: This course covers the main statistical methods used in reliability and life data analysis. The main distributions used in reliability data analysis are overviewed. The ageing properties of different distributions are explored. A course in reliability helps in probabilistic modeling of the reliability of systems with multiple components and statistical modeling of reliability of individual components based on lifetime data.

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.

UNIT II

Life distributions and associated survival, conditional survival and hazard rate functions. Exponential, Weibull, gamma life distributions and estimation of their parameters.

UNIT III

Notions of ageing: IFR IFRA, NBU, DMRL, NBUE, and HNBUE classes; their duals and relationships between them. Closures of these classes under formation of coherent systems, convolutions and mixtures.

UNIT IV

Partial orderings: Convex, star, stochastic, failure rate and mean-residual life orderings. Univariate shock models and life distributions arising out of them. Maintenance and replacement policies, availability of repairable systems.

Suggested Readings:

1. Barlow R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
2. Lawless J.F. (2003): Statistical Models and Methods of Life Time Data, 2nd Edition, John Wiley.
3. Shaked M. and Shanthikumar G. (2010): Stochastic Orders, Springer.
4. Nelson, W.B. (2004): Applied Life Data Analysis, Wiley-Blackwell.
5. Zacks, S. (2011): Introduction to Reliability Analysis - Probability Models and Statistical Methods, Springer.

SURVIVAL ANALYSIS

(SPMS STAT 01 02 02 DCEC 4004)

Objective: The course gives the application of statistics in handling survival data. The course introduces the concept of censoring and the various distributions used to analyze such data. Various models are also suggested to deal with survival data.

UNIT I

Concepts of Type-I (time), Type-II (failure) and random censoring, likelihood in these cases. Life distributions - exponential, gamma, Weibull, lognormal, Pareto. Linear failure rate. Inference for exponential, gamma, Weibull distributions under censoring.

UNIT II

Failure rate, mean residual life and their elementary properties. Ageing classes and their properties, bath tub failure rate.

UNIT III

Estimation of survival function – Actuarial estimator, Kaplan – Meier estimator. Tests of exponentiality against non-parametric classes: Total time on Test, Deshpande Test.

UNIT IV

Two sample problem: Gehan test, Log rank test, Mantel-Haenszel test. Cox's proportional hazards model, competing risks model.

Suggested Readings:

1. Kleinbaum, D.G. and Klein, M. (2012): Survival Analysis – A self-learning text, 3rd ed., Springer.
2. Miller, R.G. (2011): Survival Analysis, 2nd Edition, Wiley.
3. Moore, D.F. (2016): Applied Survival Analysis using R, Springer.
4. Kalbfleisch J.D. and Prentice R. (1980): The Statistical Analysis of Failure Time Data, John Wiley.
5. Klein, J.P. and Moeschberger, M.L. (2010): Survival Analysis: Techniques for Censored and Truncated Data, 2nd Edition, Springer.

OPERATIONS RESEARCH AND QUEUING THEORY

(SPMS STAT 01 02 03 DCEC 4004)

Objective: To provide the ideas of formulating mathematical modeling and their optimum solution in the context of practical problems belonging to Govt./Pvt. Sectors. Also, to give students a firm foundation in the advanced optimization techniques for the solution of the problems covered in course contents.

UNIT I

Origin and development of operations research (O.R.), modelling in O.R., applications of O.R., opportunities and shortcomings of O.R. Formulation of linear programming problem (LPP), graphical solution to LPP, properties of a solution to the LPP, generating extreme point solutions.

UNIT II

The simplex computational procedure, development of minimum feasible solution, a first feasible solution using slack variables, the artificial basis technique. Two phase method and Charnes M-method with artificial variables.

UNIT III

The duality problem of linear programming and its economic interpretation, transportation and assignment problems. Queueing Theory: Introduction of the queuing system, Various components of a queueing system.

UNIT IV

Pure Birth Process; Pure Death Process, Birth and Death Process, M/M/1 , M/M/1 (Generalised), M/M/1/FCFS/K/∞, M/M/C, Erlang's loss model.

Suggested Readings:

1. Hillier, F.S. and Liebermann, G.J. (2009): Introduction to Operations Research; 9th Edition, McGraw Hill.
2. Gass, S.I. (2010): Linear Programming, Methods and Applications, 5th Edition, Dover Books.
3. Kanti Swarup, Gupta,P.K. and Singh, M.M. (2010): Operations Research, Sultan Chand and Sons.
4. Saaty, T.L. (1984): Elements of Queueing Theory with applications, McGraw Hill, New York.
5. Jain, J.L., Mohanty, S.G. and Bohm, W. (2006): A Course on Queueing Models, Chapman & Hall/CRC.

STATISTICAL COMPUTING USING C

(SPMS STAT 01 02 04 DCEC 4004)

Objective: The objective of this course is to introduce students with basic knowledge of a computer system and to train them in the middle level computer programming language 'C'.

UNIT I

C Programming Language: Basic features of C language, constants, variables and data types, operators and expressions - arithmetic, relational and logical. Input and output statements with their formats, decision making statements, branching and looping, arrays, user and system defined functions, structures and pointers.

UNIT II

C Programs for Statistical Methods: Measures of central tendency and dispersion. Moments, correlation, regression, curve fitting. Tests of significance: t-test and Chi-Square test for given data.

C Programs for Matrix Algebra: Addition, Multiplication, Transpose, Determinant and Inverse of Matrices. Solution of system of Linear Equations.

UNIT III

C Programs for Numerical Methods: Roots of algebraic and transcendental equations by Bisection and Newton-Rapson methods. Difference table, Newton's forward and backward formulae, Lagrange's formulae for interpolation, Numerical integration, Trapezoidal, Simpson's $1/3^{rd}$ and $3/8^{th}$ rules.

UNIT IV

Properties of Statistical Distributions: Calculating pmf and cdf of Uniform, Binomial, Poisson, Normal, Cauchy, Gamma, Beta, Students' t and Chi-square distributions, Generation of random numbers from these distributions.

Suggested Readings:

1. Balagurusamy, E. (2012): Programming in ANSI C, 6th ed., Tata Mc-Graw Hill, New Delhi..
2. Kanetkar Y.P. (2016): Let us C, 14th ed., BPB Publications, New Delhi.
3. Kernighan, B.W. and Ritchie, D. (2015): The C Programming Language, 2nd Edition, Prentice Hall of India.

APPLIED STATISTICS

(SPMS STAT 01 02 01 GEC 3014)

Objective: The course aims to study various models and components of time series analysis for forecasting purposes and various methods to control the quality of a product. It also gives the study of distribution of population with respect to birth, migration, aging and death.

UNIT I

Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series, measurement of trend by method of moving averages, method of semi-averages and method of least squares (linear, quadratic and modified exponential).

UNIT II

Measurement of seasonal variations by method of simple averages, method of ratio to trend. Statistical Quality Control: Importance of statistical methods in industrial research and practice, determination of tolerance limits, causes of variations in quality: chance and assignable.

UNIT III

General theory of control charts, process and product control, control charts for variables: X- bar and R-charts, control charts for attributes: p and c-charts. Demographic Methods: Introduction, measurement of population, rates and ratios of vital events, measurement of mortality: CDR, SDR (w.r.t. age and sex), IMR, Standardized death rates.

UNIT IV

Life (mortality) tables: definition of its main functions and uses, measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR.

Suggested Readings:

1. Mukhopadhyay, P. (2011): Applied Statistics, 2nd Edition, Books and Allied (P.) Ltd.
2. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.
3. Montegomery, D.C. (2013): Statistical Quality Control: A Modern Introduction, 7th Edition, Wiley.

OPERATIONS RESEARCH

(SPMS STAT 01 02 02 GEC 4004)

Objective: To provide the ideas of formulating mathematical modeling and their optimum solution in the context of practical problems belonging to Govt./Pvt. Sectors. Also, to give students a firm foundation in the advanced optimization techniques for the solution of the problems covered in course contents.

UNIT I

Origin and development of operations research (O.R.), modelling in O.R., applications of O.R., opportunities and shortcomings of O.R. Formulation of linear programming problem (LPP), graphical solution to LPP, properties of a solution to the LPP, generating extreme point solutions.

UNIT II

The simplex computational procedure, development of minimum feasible solution, a first feasible solution using slack variables, the artificial basis technique.

UNIT III

Two phase method and Charnes M-method with artificial variables. The duality problem of linear programming and its economic interpretation, transportation and assignment problems. Sensitivity analysis, network flow problem.

UNIT IV

Game theory problem as a linear programming problem, integer programming. Replacement models and sequencing theory, inventory models with single and multiple periods.

Suggested Readings:

1. Hillier, F.S. and Liebermann, G.J. (2009): Introduction to Operations Research; 9th Edition, McGraw Hill.
2. Gass, S.I. (2010): Linear Programming, Methods and Applications, 5th Edition, Dover Books.
3. Kanti Swarup, Gupta,P.K. and Singh, M.M. (2010): Operations Research, Sultan Chand and Sons.

DESIGN OF EXPERIMENTS

(SPMS STAT 01 03 01 CC 4004)

Objective: To provide orientation of statistics while designing statistical experiments, particularly in agricultural set-up and in pharmaceutical production processes. Exposure to various statistical designs leading to the analysis of variance, eliminating heterogeneity of the data, construction of designs will be provided.

UNIT I

Introduction to design of experiments. Three basic principles of design of experiments: randomisation, replication and local control. Uniformity trials. Analysis of basic design, asymptotic relative efficiency, missing plot techniques, analysis of covariance for CRD and RBD.

UNIT II

Factorial experiments: 2^k, 3^2 and 3^3 systems only. Complete and partial confounding, factorial replication in 2^k systems. Two-level fractional factorial designs: introduction, the one-quarter fraction of the 2^k design. Alias structure in fractional factorials and other designs.

UNIT III

Incomplete block design: balanced incomplete block design, simple lattice design, split-plot design, strip-plot design, comparison of two treatments, efficiency of BIBD relative to RBD.

UNIT IV

Response surface methodology, first order designs, and orthogonal designs, treatment-control designs, model variation and use of transformation, cross-over designs: 2x2 and 3x3 cross-over designs.

Suggested Readings:

1. Montgomery, D.C. (2013): Design and Analysis of Experiments, 8th Edition, Wiley India (P) Ltd.
2. Toutenburg, H. and Shalabh (2010): Statistical Analysis of Designed Experiments, 3rd Edition, Springer.
3. Cobb, W. Georg (2008): Introduction to Design and Analysis of Experiments, John Wiley & Sons Inc.
4. Lawson, J. (2014): Design and Analysis of Experiments with R, CRC Press.

ECONOMETRICS

(SPMS STAT 01 03 02 CC 4004)

Objective: The purpose of this course is to give students a solid foundation in econometric techniques, various functions for economic analysis and future forecasting. Many of the methods introduced in this course are also useful in business, finance and many other disciplines.

UNIT I

Introduction to econometrics. A review of least squares and maximum likelihood estimation methods of parameters in classical linear regression model and their properties. Generalized least squares estimation and prediction, construction of confidence regions and tests of hypotheses, use of dummy variables and seasonal adjustment.

UNIT II

Regression analysis under linear restrictions, restricted least squares estimation method and its properties. Problem of Multicollinearity, its implications and tools for handling the problem. Ridge regression. Hetroscedasticity, consequences and tests for it, estimation procedures under hetroscedastic disturbances, Bartlett's test, Breusch Pagan test and Goldfelf Quandt test.

UNIT III

Autocorrelation, sources and consequences, Autoregressive process tests for autocorrelation, Durbin Watson test. Asymptotic theory and regressors. Instrumental variable estimation, errors in variables.

UNIT IV

Simultaneous equations model, problem of identification, necessary and sufficient condition for the identifiability of parameters in a structural equation, ordinary least squares, indirect least squares, two-stage least squares and limited information maximum likelihood method.

Suggested Readings:

1. Gujrati, D. and Porter, D. (2009): Basic Econometrics, 5th Edition, McGraw Hill.
2. Maddala, G.S. and Lahiri, K. (2010). Introduction to Econometrics, 4th Edition, Wiley.
3. Greene, W. H. (2012): Econometric Analysis, 7th Edition, Pearson.
4. Studenmund, A.H. and Johnson, B.K. (2017): Using Econometrics A Practical Guide, 7th Edition, Pearson.
5. Baltagi, B.H. (2014): Econometrics, 5th Edition, Springer.

STATISTICAL INFERENCE - II

(SPMS STAT 01 03 03 CC 4004)

Objective: The objective of this course is to apprise the students about various techniques of hypothesis testing when the assumptions of parametric set up are not fulfilled. Thrust will be to study various nonparametric analogues to one, two and c-sample location problems as well as two sample scale problem.

UNIT I

Concept of nonparametric and distribution-free methods, probability integral transformation, empirical distribution function, kernel, one-sample and two-sample *U*-Statistics, UMVUE property and asymptotic distribution of *U*-Statistics. Rank order statistics, treatment of ties in rank tests, linear rank statistics, distribution and properties of linear rank statistics.

UNIT II

Tests of randomness: Tests based on total number of runs, exact null distribution of *R*, asymptotic null distribution of *R*, tests based on runs up and down and related applications. The Chi-square goodness-of-fit test, the Kolmogorov-Smirnov one-sample statistic. The Sign test and Wilcoxon Signed Rank test for one-sample and paired sample problems.

UNIT III

Independence in bivariate sample: Kendall's and Spearman's rank correlation. The general two-sample problem: median test, Mann-Whitney test, Wilcoxon Rank Sum test, Terry-Hoeffding (Normal Scores) test. Tests for scale problem: Mood test, Klotz Normal-Scores test, and Sukhatme test.

UNIT IV

Tests for *k* independent samples: Kruskal-Wallis one-way ANOVA test and multiple comparisons, Jonckheere-Terpstra test for ordered alternatives. Friedman's two-way ANOVA by ranks. Asymptotic relative efficiency (ARE): Theoretical basis for calculating the ARE, Examples of the calculation of efficacy and ARE.

Suggested Readings:

1. Gibbons, J.D. and Chakraborti, S. (2010): Nonparametric Statistical Inference, 5th Edition, CRC Press.
2. Hollander, M., Wolfe, D. and Chicken, E. (2013): Nonparametric Statistical Methods, 3rd Edition, Wiley.
3. Bonnini, S., Corain, L., Marozzi, M. and Salmaso, L. (2014): Nonparametric Hypothesis Testing Rank and Permutation Methods with Applications in R, 1st Edition, Wiley.
4. Sprent, P. and Smeeton N.C. (2007): Applied Nonparametric Statistical Methods, 4th Edition, CRC Press.

PRACTICAL

(SPMS STAT 01 03 04 CC 0033)

Practicals based on Design of Experiments (SPMS STAT 01 03 01 CC 4004), Econometrics (SPMS STAT 01 03 02 CC 4004) and Statistical Inference - II (SPMS STAT 01 03 03 CC 4004).

TIME SERIES AND STATISTICAL QUALITY CONTROL

(SPMS STAT 01 03 01 DCEC 4004)

Objective: The objective of this course is to equip the students of M.Sc. Statistics with knowledge of industrial statistics as well as applications of Time series in real life.

UNIT I

Time series: the nature and uses of forecasts, examples of time series, forecasting process, time series plots, plotting smoothed data, stationary time series. Auto covariance and auto correlation functions, forecasting model evaluation, choosing between competing models. First order exponential smoothing, modelling time series data. Second order exponential smoothing. Exponential smoothing for seasonal data. Linear models for stationary time series.

UNIT II

First order moving average (MA(1)) process, second order moving average (MA(2)) process. First order autoregressive process (AR(1)), second order autoregressive process (AR(2)). Autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) models. Choice of AR and MA periods. Non-stationary process. Time series model building: model identification, parameter estimation, diagnostic checking. Estimation of ARIMA model parameters, forecasting ARIMA processes.

UNIT III

The meaning of quality, quality assurance, technology and productivity. Statistical methods for quality control and improvement. Chance and assignable causes of quality variation, general theory of control charts, control charts for variables: $\bar{X}$ and R chart, analysis of pattern on control charts, control chart for attributes- *np*, *p*, *c* and *u* charts.

UNIT IV

Specification limits and tolerance limits, OC and ARL of control charts, CUSUM charts using V-mask. ARL of CUSUM charts, single, double and sequential sampling plans and their properties, including OC, AOQL and ASN curves. Specification of sampling plan by LTPD and AOQL.

Suggested Readings:

1. Montgomery,D.C., Jennings, C.L. and Kulahci, M. (2015): Introduction to Time Series Analysis and Forecasting, 2nd Edition, Wiley.
2. Brockwell, P.J. and Davis R.A. (2016): Introduction to Time Series and Forecasting, 2nd Edition, Springer.
3. Montgomery, D.C. (2012): Introduction to Statistical Quality Control, 7th Edition, Wiley.
4. Grant, E. and Leavenworth, R. (2012): Statistical Quality Control, 7th Edition, Tata McGraw Hill.

BIO-STATISTICS

(SPMS STAT 01 03 02 DCEC 4004)

Objective: The course gives the application of statistics in handling survival data. The course introduces the concept of censoring and the various distributions used to analyse such data. Various models are also suggested to deal with survival data.

UNIT I

Functions of survival time, survival distributions and their applications viz. exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shape hazard function. Tests of goodness of fit for survival distributions.

UNIT II

Analysis of epidemiologic and clinical data: studying association between a disease and a characteristic: (a) types of studies in epidemiology and clinical research (i) prospective study retrospective study (iii) cross-sectional data, (b) dichotomous response and dichotomous risk factor: 2x2 tables (c) expressing relationship between a risk factor and a disease (d) inference for relative risk and odds ratio for 2x2 table, sensitivity, specificity and predictivity. Cox proportional hazard model.

UNIT III

Type I and type II censoring schemes with biological examples, estimation of mean survival time and variance of the estimator for type I and type II censored data with numerical examples. Non-parametric methods for estimating survival function and variance of the estimator. Competing risk theory, indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death under competing risks by maximum likelihood. Theory of independent and dependent risks.

UNIT IV

Stochastic epidemic models: simple and general epidemic models (by use of random variable technique). Basic biological concepts in genetics, Mendels law, Hardy-Weinberg equilibrium, random mating, distribution of allele frequency (dominant/co-dominant cases), approach to equilibrium for X-linked genes, natural selection, mutation, genetic drift, equilibrium when both natural selection and mutation are operative, detection and estimation of linkage in heredity.

Suggested Readings:

1. Collett, D. (2014). Modelling Survival Data in Medical Research, 3rd Edition, Chapman & Hall/CRC.
2. Friedman, L.M., Furburg, C.D., DeMets, D.L., Reboussin and Granger, C.B. (2015). Fundamentals of Clinical Trials, 5th Edition, Springer.
3. Indrayan, A. (2012). Medical Biostatistics, 3rd Edition, Chapman & Hall/CRC.
4. Lee, E.T. and Wang J.W. (2013). Statistical Methods for Survival Data Analysis, Wiley.

STOCHASTIC PROCESS

(SPMS STAT 01 03 03 DCEC 4004)

Objective: The objective of this course is to apprise the students with the basic concepts of the theory of stochastic processes in continuous time, also to make them able to use various analytical and computational techniques to study stochastic models that appears in applications.

UNIT I

Stochastic Processes: Introduction, classification according to state space and time domain. Countable state Markov chains, transition probability matrix, Chapman-Kolmogorov equations, calculation of n-step transition probabilities and their limits, stationary distribution.

UNIT II

Branching Processes: Properties of generating function of branching processes, probability of ultimate extinction, distribution of the total number of progeny, generalization of the classical Galton-Watson branching process, general branching processes, random walk and gambler's ruin problem.

UNIT III

Continuous-time Markov Processes: Poisson process and related distributions, generalizations of Poisson process, simple birth-process, simple death-process, simple birth-death process, linear birth-death process. First passage time distribution.

UNIT IV

Renewal Theory: Elementary renewal theorem and applications. Statement and uses of key renewal theorem, central limit theorem for renewals, study of residual and excess lifetime's process. Renewal reward Process, Markov renewal and semi- Markov processes, Markov renewal equations.

Suggested Readings:

1. Medhi, J. (2012): Stochastic Processes, 3rd Edition, New Age International.
2. Ross, S.M. (2008): Stochastic Processes, 2nd Edition, Wiley India.
3. Karlin, S. and Taylor, H.M. (2012): A First Course in Stochastic Processes, 2nd Edition, Academic Press.
4. Prabhu, N.U. (2007): Stochastic Processes: Basic Theory and its Applications, World Scientific.

DEMOGRAPHY AND VITAL STATISTICS

(SPMS STAT 01 03 04 DCEC 4004)

Objective: The objective of the course is to make the students conversant with various techniques used in summarization and analysis of data related to demographic and vital events.

UNIT I

Coverage and content errors in demographic data, use of balancing equations and Chandrasekharan-Deming formula to check completeness of registration data, adjustment of age data. Use of Whipple, Myer and UN indices, population composition, dependency ratio, population transition theory.

UNIT II

Measures of Fertility: Stochastic models for reproduction, distribution of time to first birth, inter-live birth intervals and of number of births. Estimation of parameters, estimation of parity progression ratio from open birth interval data.

UNIT III

Measures of Mortality: Construction of abridged life tables, distribution of life table functions and their estimation. Stable and quasi-stable populations, intrinsic growth rate models for population growth and their fitting to population data. Stochastic models for population growth.

UNIT IV

Stochastic models for migration and for social and occupational mobility based on Markov chains. Estimation of measures of mobility. Methods for population projection. Use of Leslie matrix. Nuptuality and its measurements.

Suggested Readings:

1. Kumar, R. (2006): Technical Demography, New age International (P) Ltd, New Delhi.
2. Samuel, P., Patrick, H. and Michel, G. (2000): Demography: Measuring and Modeling Population Processes, Wiley-Blackwell.
3. Rowland, D.T. (2003): Demographic Methods and Concepts, Oxford university press, Inc., New York.
4. Pathak, K. B. and Ram, F. (2013): Techniques of Demographic Analysis, Himalaya Publishing House.
5. Keyfitz, N. and Caswell, H. (2005): Applied Mathematical Demography, Springer.

ORDER STATISTICS

(SPMS STAT 01 03 05 DCEC 4004)

Objective: The objective of the course is to learn general strategies for problems about order statistics and how to learn to find the median (or k-th largest) in linear average-case number of comparisons (and time).

UNIT I

Introduction to order statistics, joint, marginal and conditional distributions of order statistics (discrete and continuous cases). Distribution of the range and other systematic statistics, order statistics as a Markov chain. Examples based on discrete and continuous distributions.

UNIT II

Distribution-free confidence intervals for population quantiles and distribution-free tolerance intervals. Distribution-free bounds for moments of order statistics and of the range. Approximations to moments in terms of the quantile function and its derivatives.

UNIT III

Moments of order statistics, recurrence relations and identities for moments of order statistics. Large sample approximations to mean and variance of order statistics. Asymptotic distributions of order statistics.

UNIT IV

Order statistics for independently and not identically distributed (i.ni.d.) variates, Concomitants of order statistics. Random division of an interval and its applications. Order statistics from a sample containing a single outlier. Concepts of record values and generalized order statistics.

Suggested Readings:

1. Arnold, B.C., Balakrishnan, N. and Nagaraja, H.N. (2008): A First Course in Order Statistics, SIAM Publishers.
2. David, H.A. and Nagaraja, H.N. (2003): Order Statistics, 3rd Edition, John Wiley & Sons.
3. Balakrishnan, N. and Cohen, A.C. (1991): Order Statistics and Inference: Estimation Methods, Academic Press, San Diego.
4. Ahsanullah, M., Nevzorov, V.B. and Shakil, M. (2013): An Introduction to Order Statistics, Atlantis Studies in Probability and Statistics, Vol. 3, Atlantis Press.
5. Kamps, U. (1995): A Concept of Generalized Order Statistics, Springer.

SIMULTANEOUS INFERENCE

(SPMS STAT 01 03 06 DCEC 4004)

Objective: The main objective of the course is to test several hypotheses simultaneously at a pre-specified level and construction of simultaneous confidence intervals.

UNIT I

Introduction to simultaneous inference, families, error rates, allocation of errors. Bonferroni inequality, *p*-mean significance levels, basic techniques of multiple comparisons and their geometrical interpretation for the case of two means.

UNIT II

Normal univariate techniques: Tukey's studentized range, Scheffe's *F*-projections, Bonferroni *t*-statistics, studentized maximum modulus, many-one *t*-statistics, Duncan's multiple range test, Fisher's least square difference test, Tukey's gap-straggler-variance test, two-sample confidence intervals of pre-determined length and improved Bonferroni inequality.

UNIT III

Nonparametric techniques: Steel's many-one sign statistics, *k*-sample sign statistics, Steel's many-one rank statistics, *k*-sample rank statistics, signed-rank statistics, Kruskal-Wallis rank statistics, Friedman rank statistics, and permutation test.

UNIT IV

Multivariate techniques: single population with covariance scalar unknown, single population with covariance matrix unknown, *k* populations with covariance matrix unknown.

Suggested Readings:

1. Miller, R.G. (2013): Simultaneous Statistical Inference, 2nd Edition reprint, Springer.
2. Dickhaus, T. (2014): Simultaneous Statistical Inference – With Applications in the Life Sciences, 1st Edition, Springer.
3. Hochberg, Y. and Tamhane, A.C. (2011): Multiple Comparison Procedures, 1st Edition, Wiley.
4. Bretz, F., Hothorn, T. and Westfall, P. (2010). Multiple Comparisons Using R, 1st Edition, CRC Press.

Multivariate Analysis

(SPMS STAT 01 04 01 CC 4004)

Objectives: Multivariate analysis is the analysis of observations on several correlated random variables for a number of individuals. This analysis has been used in almost all scientific studies. For example, the data may be the nutritional anthropometrical measurements like height, weight, arm circumference, chest circumference, etc. taken from randomly selected students to assess their nutritional studies. Since here we are considering more than one variable this is called multivariate analysis.

UNIT I

Multivariate normal distribution, its properties and characterization. Random sampling from a multivariate normal distribution. Maximum likelihood estimators of parameters. Distribution of sample mean vector. Inference concerning the mean vector when the covariance matrix is known. Matrix normal distribution. Multivariate central limit theorem.

UNIT II

Wishart matrix, its distribution and properties. Distribution of sample generalized variance. Hotelling's T^2 statistic and its distribution and properties. Applications in tests on mean vector for one and more multivariate normal populations. Mahalanobis' D^2.

UNIT III

Likelihood ratio test criteria for testing of independence of sets of variables, equality of covariance matrices, identity of several multivariate normal populations, equality of a covariance matrix to a given matrix, equality of a mean vector and a covariance matrix to a given vector and a given matrix.

UNIT IV

Classification and discrimination procedures for discrimination between two multivariate normal populations, sample discriminant function, tests associated with discriminant functions, classification into more than two multivariate normal populations. Principal components, canonical variables and canonical correlations. Multivariate analysis of variance [MANOVA] of one-way classified data. Wilk's lambda criterion.

Suggested Readings:

1. Johnson, R.A. and Wichern, D.W.: (2015). Applied Multivariate Statistical Analysis, Sixth Edition, Pearson Education India.
2. Hardle, W.K. and Hlavka, Z. (2015): Multivariate Statistics, Springer.
3. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, Third Edition, Wiley.
4. Härdle, W.K. and Simar, L. (2015): Applied Multivariate Statistical Analysis, Springer.
5. Singh, B.M. (2004): Multivariate statistical analysis, South Asian Publishers.

BAYESIAN INFERENCE

(SPMS STAT 01 04 02 CC 4004)

Objectives: The main objective of the course is to provide the detailed knowledge of the characterization of another inferential procedure that is Bayesian Inference.

UNIT I

Elements of the Bayesian paradigm, subjective probability, its existence and interpretation. Bayes theorem for random variables. Introduction to prior and posterior distributions, loss functions. Bayes risks, Bayesian paradigm versus classical paradigm.

UNIT II

Prior distribution, subjective determination of prior distribution, improper priors, non-informative priors, scale invariant prior, location invariant prior, conjugate prior families, construction of conjugate families using sufficient statistic for fixed dimensions, mixture of conjugate priors, hierarchical priors and partial exchangeability.

UNIT III

Bayesian estimation of parameters of some well-known distributions: Binomial, multinomial, Poisson, normal, lognormal, exponential, Rayleigh and Weibull distributions. Empirical and hierarchical Bayes estimation, Bayesian sufficiency, summary through posterior and predictive inference.

UNIT IV

Bayesian Interval Estimation: Credible and highest posterior density (HPD) interval, HPD credible intervals in case of Binomial, multinomial, Poisson, normal, lognormal, exponential, Rayleigh and Weibull distributions. Predictive distribution and reliability estimation for Binomial, multinomial, Poisson, normal, lognormal, exponential, Rayleigh and Weibull distributions.

Suggested Readings:

1. Berger, J.O. (2013): Statistical Decision Theory and Bayesian Analysis, Springer.
2. Robert, C.P. and Casella, G. (2013): Monte Carlo Statistical Methods, Springer.
3. Bernando, J.M. and Smith, A.F.M. (2008): Bayesian Theory, Wiley.
4. Kelly, D. and Smith, C. (2011): Bayesian Inference for Probabilistic Risk Assessment: A Practitioner' Guidebook, Springer.

PRACTICAL
(SPMS STAT 01 04 03 CC 0044)

Practicals based on Multivariate Analysis (SPMS STAT 01 04 01 CC 4004) and Bayesian Inference (SPMS STAT 01 04 02 CC 4004).

GENERALIZED LINEAR MODELS

(SPMS STAT 01 04 01 DCEC 4004**)**

Objectives: The students will get familiar with the need of modelling random responses using independent predictors through linear and logistic (for binary responses) models in real life situations. Least square estimation of parameters of these models will be discussed along with their statistical significance.

UNIT I

Review of Linear models, least square model fitting, Testing the general linear hypothesis: t-test and F-test. Simple linear regression. Multiple linear regression. Interpretation of the coefficients. Residuals, Leverage and influence. Optimality of least squares and generalized least squares.

UNIT II

Binary data. The binomial distribution. Grouped and ungrouped data. Odds and log-odds. The logit transformation. Logistic regression. Maximum likelihood estimation and testing in logistic regression models. The comparison of two groups. The odds ratio. Comparison of several groups. Regression models for binary data. Models with two predictors. Main effects and interactions. Multifactor models. Model selection. Alternative links for binary data. Probit analysis. The c-log-log link. Regression diagnostics with binary data.

UNIT III

Count data. The Poisson distribution. The log link. Maximum likelihood estimation and testing in Poisson regression. The Poisson deviance. Modelling heteroscedastic counts. Models for rates of events. Exposure and the use of an offset in the linear predictor. Extra-Poisson variation. The negative binomial model. Zero-inflated models for counts. Multinomial response models.

UNIT IV

Multinomial logits. Independence of irrelevant alternatives. Random utilities and the conditional logit model. Sequential logits. Sequential binary choice and continuation ratio models. Equivalence with logit models. Models for ordered categorical data. Ordered logits and probits. Latent variable formulation and interpretation of the coefficients.

Suggesting Readings:

1. Myers, R.H, Monetgomery, D.C., Vining, G.G. and Robinson, T.J. (2010): Generalized Linear Models with Applications in Engineering and the Sciences, Second Edition, Wiley.
2. Stroup, W. W. (2013): Generalized Linear Mixed Models: Modern Concepts, Methods and Applications, CRC Press.
3. Agresti, A. (2015): Foundations of Linear and Generalized Linear Models, Wiley.
4. Dobson, A.J. and Barnett, A.G. (2008): Introduction to Generalized Linear Models, Third Edition, CRC Press.

CATEGORICAL DATA ANALYSIS

(SPMS STAT 01 04 02 DCEC 4004)

Objectives: This course deals with the analysis of categorical data measured on different scales. The estimation and testing techniques related to various advance models are discussed. Fitting of models and strategies in model selection are also discussed.

UNIT I

Categorical response variables: Nominal, ordinal, interval. Probability structure for contingency tables: joint, marginal and conditional probabilities, sensitivity and specificity, independence. Comparing proportions in 2x2 Tables: difference of proportions, relative risk. Odds Ratio: definitions and properties of odds ratio with examples, inference for odds ratio and log odds ratio, relationship between odds ratio and relative risk. Chi-square tests of independence: Pearson statistic, likelihood ratio statistic, tests of independence, partitioning Chi-squared.

UNIT II

Testing independence for ordinal data: linear trend alternative to independence, extra power with ordinal test, choice of score, trend tests for Ix2 and 2xJ tables, nominal-ordinal tables. Exact inference for small samples: Fisher's exact test for 2x2 table, p-values and conservatism for actual P(Type I error), small sample confidence interval for odds ratio. Association in three-way table: partial tables, conditional versus marginal associations, Simpson's paradox, conditional and marginal odds ratios, conditional independence versus marginal independence, homogeneous associations.

UNIT III

Models for binary response variables: logit, log linear, linear probability and logistic regression models. Logit models for categorical data, probit and extreme value models, models with log-log link, model diagnostics. Fitting logit models, conditional logistic regression, exact trend test. Loglinear models for two dimensions - independence model, saturated model and models for cell probabilities.

UNIT IV

Loglinear models for two-way and three-way tables: loglinear model of independence for two-way table, saturated model for two-way tables, loglinear models for three-way tables. Inference for loglinear models: Chi-squared goodness of fit tests, loglinear cell residuals, tests about conditional associations, confidence intervals for conditional odds ratios, three factor interactions, large samples and statistical versus practical significance.

Suggesting Readings:

1. Agresti, A. (2013): Categorical Data Analysis, Third Edition, Wiley.
2. Upton, G.J.G. (2017): Categorical Data Analysis by Example, Wiley.
3. Sutradhar, B. C. (2014): Longitudinal Categorical Data Analysis, Springer.
4. Bilder, C. R. And Loughin, T.M. (2013): Analysis of Categorical Data with R, CRC Press.

DECISION THEORY AND SEQUENTIAL ANALYSIS

(SPMS STAT 01 04 03 DCEC 4004)

Objectives: The main objective of this course is to provide the detailed knowledge of the decision theory and sequential analysis.

UNIT I

Elements of decision theory: Expected loss, decision rules and risks - Bayesian expected loss, frequentist risks, randomized and nonrandomized decision rules, admissible decision rule, complete, essential complete and minimal complete classes of decision rules and their relationship, minimax and Bayes decision rule, estimation testing viewed as decision rule problem, Bayes and minimax estimators. Minimax and Bayes tests in simple cases.

UNIT II

Decision principles: the conditional Bayes decision principle and frequentist decision principles. Misuse of classical Inference procedures, the frequentist perspective, the conditional perspective, the likelihood principle, choosing a paradigm or decision principle. Utility theory: introduction, the utility of money.

UNIT III

Bayesian decision theory: Posterior decision analysis, estimation, finite action problems and hypothesis testing. Minimax Analysis: Introduction, game theory, basic elements, general techniques for solving games, finite games, the minimax theorem.

UNIT IV

The sequential probability ratio test (SPRT) and its application to Binomial, normal and other simple cases, operating characteristic (OC) function of SPRT, Average Sample Number (ASN) function and their application, Wald's fundamental identity and its uses.

Suggested Readings:

1. Robert, C.P. (2013): The Bayesian Choice: A Decision Theoretic Motivation, Springer.
2. Berger J.O. (2013): Statistical Decision Theory and Bayesian Analysis, Springer.
3. Wald, A. (2013): Sequential Analysis, Dover Publications.
4. Mukhopadhyay, N. and de Silva, B.M. (2008): Sequential Methods and Their Applications, CRC Press.

STATISTICAL SIMULATION AND COMPUTATION

(SPMS STAT 01 04 04 DCEC 4004)

Objectives: The students will study the statistical simulation using Computers. It contains introduction to System, Models, Simulation, Random Number Generation and Variance Reduction Techniques.

UNIT I

Introduction and need of statistical simulation. Random number generation, requisites of a good random number, methods of random number generation such as linear congruential and mixed congruential, statistical tests for pseudo random numbers. Methods of generating random variables such as inverse transforms, composition and acceptance-rejection methods.

UNIT II

Monte Carlo integration and variance reduction techniques: Hit or miss Monte Carlo method, sample mean Monte Carlo method, importance sampling, correlated sampling control variates, stratified sampling, antithetic variates, partition of region.

UNIT III

EM algorithm: applications to missing and incomplete data problems, mixture models. Smoothing with kernels, density estimation, simple non-parametric regression. Smoothing with kernels: density estimation, choice of kernels.

UNIT IV

Simulation based testing: simulating test statistics and power functions, permutation tests. Bootstrap methods: resampling paradigms, bias and standard errors, confidence intervals, bootstrapping in regression. Jackknife and cross validation: Jacknife in sample surveys, cross-validation for tuning parameters.

Suggesting Readings:

1. Rubinstein, R.Y. and Kroese, D.P. (2008): Simulation and the Monte Carlo Method, Second Edition, Wiley.
2. Voss, J. (2014): An Introduction to Statistical Computing: A Simulation Approach, Wiley.
3. Ross, S.M. (2012): Simulation, Fifth Edition, Academic Press.
4. Thomopoulos, N.T. (2013): Essentials of Monte Carlo Simulation, Springer.

ACTUARIAL STATISTICS

(SPMS STAT 01 04 05 DCEC 4004)

Objectives: 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

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. Multiple life functions, joint life and last survivor status.

UNIT II

Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement. Distribution of aggregate claims, compound Poisson distribution and its applications. Claim Amount distributions, approximating the individual model, Stop-loss insurance.

UNIT III

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor. Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance. Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, varying annuities.

UNIT IV

Net premiums: Continuous and discrete premiums, true monthly payment premiums. Net premium reserves: Continuous and discrete net premium reserves, reserves on a semi continuous basis, reserves based on true monthly premiums.

Suggested Readings:

1. Tse, Y. K. and Chan, W. S (2017): Financial Mathematics For Actuaries, World Scientific.
2. Medina, P.K. and Merino, S. (2003): A discrete introduction: Mathematical finance and Probability, Birkhauser.
3. Vecer, J. (2017): Stochastic Finance: A Numeraire Approach, CRC Press.
4. Perna, C. and Sibillo, M. (2016): Mathematical and Statistical Methods for Actuarial Sciences and Finance, Springer.