DEPARTMENT OF STATISTICS

Scheme and Syllabus
M.Sc. (Statistics)
w.e.f. 2017-18

CENTRALUNIVERSITY OF HARYANA
JANT-PALI, MAHENDERGARH
HARYANA-123031

Department of Statistics
CentralUniversity 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.	Introductory 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	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	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.	Nonparametric Inference	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 Processes	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

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. Bartle, R.G. & Sherbert, D.R. (2011). Introduction to Real Analysis, 4th Edition. Wiley.
2. Saff, E.B. & Snider, A.D. (2014). Fundamentals of Complex Analysis with Applications to Engineering, Science and Mathematics, 3rd Edition. Pearson.
3. Rudin, W. (2013). Principles of Mathematical Analysis, 3rd Edition. McGraw Hill.
4. 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

Meaning, need and importance of statistics. Attributes and variables, measurement and measurement scales. Collection and tabulation of data, diagrammatic representation of frequency distribution. Measures of central tendency, dispersion (including box and whisker plot), skewness and kurtosis. Moments. Data on two attributes, independence and association of attributes in 2x2 contingency tables.

UNIT II

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 method and ratio to trend method. Correlation (Karl Pearson's and Spearman's), multiple and partial correlations. Introduction of binomial, Poisson, geometric, normal and exponential distributions. Concept of population, parameter, random sample, statistic and sampling distribution. Expectations and standard errors. 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 $(\rho = 0 \; and \; \rho = \rho_0)$. Tests for proportions. Tests for multiple and partial correlation coefficients.

UNIT IV

One-way analysis of variance – fixed and random effect models. Two-way analysis of variance – fixed effect, random effect and multiple observations per cell models. Three-way Analysis of Variance. Introduction to order statistics and its distribution. Empirical Distribution Function.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I & II. World Press.
2. Daniel, W.W. & Cross, C. L. (2013). Biostatistics: A Foundation for Analysis in the Health Sciences. Wiley.
3. Das, N.G. (2012). Statistical Methods, Vol I & II. Tata McGraw Hill.
4. Hogg, R.V., McKean, J. & Craig, A.T. (2013). Introduction to Mathematical Statistics, 7th Edition. Pearson.

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. & Saleh A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
2. Rao, B.L.S.P. (2010): A First Course in Probability and Statistics. World Scientific.
3. Hogg, R.V., McKean, J. & Craig, A.T. (2013). Introduction to Mathematical Statistics, 7th Edition. Pearson.
4. Mukhopadhyay, P. (2015). Mathematical Statistics. New Central Book Agency.

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.

UNIT I

Introduction to sampling, census and sample surveys, sampling and non-sampling errors. Simple random sampling, sampling from finite populations with and without replacement, unbiased estimation and confidence intervals for population mean and total, simple random sampling of attributes.

UNIT II

Stratified sampling, reasons for stratification, choice of strata, choice of sampling unit, estimation of population mean and its variance, choice of sample sizes in different strata, variances of estimates with different allocation, effects of deviation from optimum allocations, estimation of the gain in precision due to stratification, cost function, construction of strata. Systematic Sampling: merits and demerits of systematic sampling, estimation of sample mean and its variance, comparison of systematic sampling with simple random and stratified sampling.

UNIT III

Ratio and regression methods of estimation, variances of the estimates, optimum property of ratio estimates, comparison among ratio, regression and simple random sampling estimates, ratio estimate in stratified sampling, comparison with the ratio and mean per unit. Cluster Sampling, estimates of mean and its variance for equal and unequal clusters, efficiency in terms of intraclass correlation, optimum unit of sampling, sampling with replacement, estimation of mean and its variance.

UNIT IV

Sampling with varying probabilities with and without replacement, sampling with probability proportional to size, Lahiri's method of selection, Horvitz-Thompson estimator, its variance and unbiased estimate of this variance. Introduction of multistage sampling, two stage sampling with equal first stage units, estimation of its mean and variance, introduction of multiphase sampling, double sampling for ratio and regression methods of estimation.

Suggested Readings:

1. Arnab, R. (2017). Survey Sampling Theory and Applications. Academic Press.
2. Singh, D. & Chaudhary, F.S. (2016). Theory and Analysis of Sample Survey Designs. New Age International Publishers.
3. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. & Ashok, C. (2014). Sampling Theory of Surveys with Applications. New Delhi: Piyush Publications.
4. Cocharn, W.G. (2007). Sampling Techniques, 3rd Edition. Wiley.

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).

INTRODUCTORY 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, Measures of Central Tendency: Mean, median, mode, geometric mean, harmonic mean. Measures of Dispersion: range, mean deviation, variance, standard deviation. Quartiles. Quartile deviation, coefficient of variation, measures of skewness, measures of kurtosis.

UNIT II

Random experiment, outcomes, sample space, events, classical definition of probability, random variables, probability mass function, probability density function, cumulative distribution function, mathematical expectation, Variance, Binomial, Poisson, Geometric, Exponential, Normal distributions.

UNIT III

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

Karl Pearson's correlation coefficient, Spearman's rank correlation coefficient, principle of least square, lines of regression, simple linear regression, coefficient of determination. Multiple linear regression, coefficient of multiple determination.

Suggested Readings:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I & II. World Press.
2. Das, N.G. (2012). Statistical Methods, Vol I & II. Tata McGraw Hill.
3. Walpole, R.E., Myers, R.H., Myers, S.L. & Ye, K.E (2012). Probability and Statistics for Engineers and Scientists. Pearson.
4. Daniel, W.W. & Cross, C.L. (2012). Biostatistics: A Foundation for Analysis in the Health Sciences, 10th Edition. Wiley.

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. Crawley, M.J. (2015). Statistics: An Introduction Using R, 2nd Edition. Wiley.
2. Crawley, M.J. (2012). The R Book, 2nd Edition. Wiley.
3. Zuur, A.F., Leno, E.N. & Meesters, E.H.W.G. (2010). A Beginner's Guide to R. Springer.
4. Maindonald, J.H. & Braun, J. (2010). Data Analysis and Graphics Using R, 3rd Edition. Cambridge University Press.

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 and Discrete Uniform distributions; their means, variances, modes, moment generating functions, cumulant generating function, probability generating functions and characteristic functions, important properties with their proofs related to these distributions.

UNIT II

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

UNIT III

Compound, truncated and mixture distributions. Non-central χ^2, t and F distributions with their properties. Multidimensional random variables, its pdf/pmf and cdf.

UNIT IV

Bivariate normal distribution with its applications and important properties. Multivariate normal distribution, its marginal and conditional distributions and related properties.

Suggested Readings:

1. Krishnamoorthy, K. (2015). Handbook of Statistical Distributions with Applications, 2nd Edition. CRC Press.
2. Rohatgi V.K. & Saleh A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. I. World Press.
4. Forbes, C., Evans, M., Hastings, N. & Peacock, B. (2010). Statistical Distributions, 4th Edition. Wiley.

STATISTICAL INFERENCE
(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. & Saleh, A.K. Md.E. (2015). An Introduction to Probability and Statistics, 3rd Edition. Wiley.
2. Lehmann, E.L. & Casella, G. (2014). Theory of Point Estimation, 2nd Edition. Springer.
3. Lehmann, E.L. & Romano, J.P. (2010). Testing Statistical Hypotheses, 3rd Edition. Springer.
4. Casella, G. & Berger, R.L. (2013). Statistical Inference, 2nd Edition. Cengage Learning.

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

Gauss-Markov linear Models, Estimable functions, Least-squares estimation, distributional properties of ordinary least-squares estimation, Normal equations, Gauss-Markov theorem, generalized least-squares estimation, least-squares estimation under linear restriction, Maximum likelihood estimation and inference concerning β. Examples and applications.

UNIT II

Simple Linear Regression: Simple linear regression model. Least-squares estimation of parameters. Hypothesis testing on the slope and intercept. Interval estimation in simple linear regression. Prediction of new observations. Coefficient of determination. Estimation by maximum likelihood.

Multiple linear regression: Multiple linear regression models. Estimation of the model parameters. Hypothesis testing in multiple linear regression. Confidence intervals in multiple regression. Coefficient of determination and Adjusted R^2.

UNIT III

Model Adequacy: Checking of linearity between study and explanatory variable, Residual Analysis, Detection and treatment of outliers, Residual plots. The PRESS statistic. Outlier test based on Studentized Residual (R-student). Test for lack of fit of the regression model.

Transformation and Weighting to Correct Model Inadequacies: Variance stabilizing transformations. Transformations to linearize the model. Analytical methods for selecting a transformation on study variable. Diagnostic for Leverage and Influence: Leverage, measures of influence.

UNIT IV

Polynomial Regression Models: Polynomial models in one variable. Orthogonal Polynomials. Piecewise polynomial (Splines).

Variable Selection and Model Building: Incorrect model specifications. Evaluation of subset regression model. Computational techniques for variable selection.

Logistic Regression: Introduction, Linear predictor and link functions, logit, probit, odds ratio, test of hypothesis.

Suggested Readings:

1. Montegomery, D.C., Peck, E.A. & Vining, G.G. (2015). Introduction to Linear Regression Analysis, 5th Edition. Wiley.
2. Khuri, A.I. (2010). Linear Model Methodology. CRC Press.
3. Rao, C.R. (2009). Linear Statistical Inference and its Applications, 2nd Edition. Wiley.
4. Draper, N.R. & Smith, H. (2011). Applied Regression Analysis, 3rd Edition. Wiley.

PRACTICAL
(SPMS STAT 01 02 04 CC 0044)

Practicals based on Distribution Theory (SPMS STAT 01 02 01 CC 4004), Statistical Inference (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. Elsayed, E.A. (2012). Reliability Engineering, 2nd Edition. Wiley.
2. Shaked, M. & Shanthikumar, G. (2010). Stochastic Orders. Springer.
3. Nelson, W.B. (2009). Applied Life Data Analysis. Wiley.
4. Zacks, S. (2011). Introduction to Reliability Analysis - Probability Models and Statistical Methods. Springer.

SURVIVAL ANALYSIS
(SPMS STAT 01 02 02 DCEC 4004)

Objective: The objective of this course is to provide the applications of statistics in handling survival data. This course introduces the concept of censoring and various life time distributions used to analyze such data.

UNIT I

Concepts of survival function, failure rate or hazard function, mean residual life and their properties. Ageing classes- IFR, DFR, IFRA, DFRA, NBU, NBUE, BT and UBT, scaled TTT transform and characterization of ageing classes.

UNIT II

Life testing plans or censoring methods, right and left censoring, concepts of Type-I (time) and Type-II (failure), random censoring schemes. Life distributions-exponential, Weibull, log-logistic, gamma, log-normal distributions. Parametric inference- estimation of parameters associated with various life time distributions and life testing plans.

UNIT III

Nonparametric methods of 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-Haenzel test. Cox proportional hazards model, competing risks model.

Suggested Readings:

1. Deshpande, J.V. & Purohit, S.G. (2016). Life Time Data: Statistical Models and Methods, 2nd Edition. Word Scientific.
2. Lee, E.T. & Wang, J.W. (2015). Statistical Methods for Survival Data Analysis, 4th Edition. Wiley.
3. Miller, R.G. (2011). Survival Analysis, 2nd Edition. Wiley.
4. Moore, D.F. (2016). Applied Survival Analysis using R. Springer.

OPERATIONS RESEARCH
(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. The duality problem of linear programming and its economic interpretation, transportation and assignment problems.

UNIT III

Inventory management: characteristics of inventory systems. Classification of items. Deterministic inventory systems with and without lead-time. All unit and incremental discounts. Single period stochastic models.

UNIT IV

Queueing Theory: Introduction of the queuing system, Various components of a queueing system. 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. Taha, H.A. (2017). Operations Research: An Introduction, 10th Edition. Pearson.
2. Gass, S.I. (2010). Linear Programming, Methods and Applications, 5th Edition. Dover Books.
3. Gross, D., Shortle, J.F., Thompson, J.M. & Harris, C.M. (2017). Fundamentals of Queueing Theory, 5th Edition. Wiley.
4. Water, D. (2013). Inventory Control and Management, 2nd Edition. Wiley.

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, 6^{th} Edition. Tata Mc-Graw Hill.
2. Kanetkar, Y.P. (2016). Let us C, 14^{th} Edition. BPB Publications.
3. Kernighan, B.W. & Ritchie, D. (2015). The C Programming Language, 2^{nd} Edition. Prentice Hall of India.
4. Kochan, S.G. (2014). Programming in C, 4^{th} Edition, Addison-Wesley.

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 exponential). Measurement of seasonal variations by method of simple averages, method of ratio to trend.

UNIT II

Statistical Quality Control: Importance of statistical methods in industrial research and practice, determination of tolerance limits, causes of variations in quality: chance and assignable. 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.

UNIT III

Demographic Methods: Introduction, measurement of population, rates and ratios of vital events, measurement of mortality: Crude Death Rate, Specific Death Rate (w. r. t. age and sex), Infant Mortality Rate, Standardized death rates.

UNIT IV

Life (mortality) tables: definition of its main functions and uses, measurement of fertility and reproduction: Crude Birth Rate, General Fertility Rate and Total Fertility Rate. Measurement of population growth: Gross Reproductive Rate, Net Reproductive Rate.

Suggested Readings:

1. Mukhopadhyay, P. (2011). Applied Statistics, 2nd Edition. Books and Allied (P.) Ltd.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016). Fundamentals of Statistics, Vol. II. 9th Edition. World Press.
3. Montegomery, D.C. (2013). Statistical Quality Control: A Modern Introduction, 7th Edition. Wiley.
4. Burr, J.T. (2014). Elementary Statistical Quality Control, 2nd Edition. CRC Press.

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.

UNIT IV

Game theory problem as a linear programming problem, integer programming. Replacement models and sequencing theory. Inventory management: characteristics of inventory systems. Classification of items. Deterministic inventory systems with and without lead-time.

Suggested Readings:

1. Taha, H.A. (2017). Operations Research: An Introduction, 10th Edition. Pearson.
2. Gass, S.I. (2010). Linear Programming, Methods and Applications, 5th Edition. Dover Books.
3. Gross, D., Shortle, J.F., Thompson, J.M. & Harris, C.M. (2017). Fundamentals of Queueing Theory, 5th Edition. Wiley.
4. Water, D. (2013). Inventory Control and Management, 2nd Edition. Wiley.

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.
2. Toutenburg, H. & Shalabh (2010). Statistical Analysis of Designed Experiments, 3rd Edition. Springer.
3. Cobb, G.W. (2014). Introduction to Design and Analysis of Experiments. Wiley.
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.N. & Porter, D.C. (2017). Basic Econometrics, 6th Edition. McGraw Hill.
2. Maddala, G.S. & Lahiri, K. (2010). Introduction to Econometrics, 4th Edition. Wiley.
3. Greene, W.H. (2012). Econometric Analysis, 7th Edition. Pearson.
4. Studenmund, A.H. & Johnson, B.K. (2017). Using Econometrics: A Practical Guide, 7th Edition. Pearson.

NONPARAMETRIC INFERENCE
(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. & Chakraborti, S. (2010). Nonparametric Statistical Inference, 5th Edition. CRC Press.
2. Hollander, M., Wolfe, D. & Chicken, E. (2013). Nonparametric Statistical Methods, 3rd Edition. Wiley.
3. Bonnini, S., Corain, L., Marozzi, M. & Salmaso, L. (2014). Nonparametric Hypothesis Testing Rank and Permutation Methods with Applications in R. Wiley.
4. Sprent, P. & Smeeton, N.C. (2013). 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 Nonparametric Inference (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. & Kulahci, M. (2015). Introduction to Time Series Analysis and Forecasting, 2nd Edition. Wiley.
2. Brockwell, P.J. & 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. & 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. CRC Press.
2. Friedman, L.M., Furburg, C.D., DeMets, D.L., Reboussin & Granger, C.B. (2015). Fundamentals of Clinical Trials, 5th Edition. Springer.
3. Indrayan, A. (2012). Medical Biostatistics, 3rd Edition. CRC Press.
4. Lee, E.T. & Wang J.W. (2013). Statistical Methods for Survival Data Analysis. Wiley.

STOCHASTIC PROCESSES
(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. (2016). Stochastic Processes, 2nd Edition. Wiley India.
3. Karlin, S. & Taylor, H.M. (2012). A First Course in Stochastic Processes, 2nd Edition. Academic Press.
4. Prabhu, N.U. (2010). 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. Rowland, D.T. (2014). Demographic Methods and Concepts. Oxford University Press.
2. Pathak, K.B. & Ram, F. (2013). Techniques of Demographic Analysis. Himalaya Publishing House.
3. Kumar, R. (2006). Technical Demography. New age International.
4. Keyfitz, N. & Caswell, H. (2010). 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. Shahbaz, M.Q., Ahsanullah, M., Shahbaz, S.H. & Al-Zahrani, B.M. (2016). Ordered Random Variables: Theory and Applications. Springer.
2. David, H.A. & Nagaraja, H.N. (2005). Order Statistics, 3rd Edition. Wiley.
3. Ahsanullah, M., Nevzorov, V.B. & Shakil, M. (2013). An Introduction to Order Statistics, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
4. Arnold, B.C., Balakrishnan, N. & Nagaraja, H.N. (2008). A First Course in Order Statistics. SIAM Publishers.