DDU Gorakhpur University, Gorakhpur

Department of Mathematics and Statistics

Syllabus

based on

National Education Policy- 2020

under

Choice Based Credit System (CBCS)

for

Ph. D. COURSE WORK

in

STATISTICS

(Effective from Session 2022-23)

Department of Mathematics and Statistics

DDU Gorakhpur University, Gorakhpur

Faculty of Science

Course Work for Ph. D. Statistics Students

Objectives:

- To develop critical thinking ability about the fundamental aspects of statistics.
- Imparting knowledge in research work in various emerging fields of statistics and its applications.
- Train the students with statistical theories, methods and computational techniques for carrying out scientific investigations independently or collaboratively in a subarea of statistics and data science

Program Specific Outcomes:

After successful completion of this program, students will:

PSO 1. have a solid foundation in Statistical Theory and Methodology.

PSO 2. be able to communicate the major tenets of statistics, explain their work orally and identify areas of future research areas in statistics.

PSO 3. gain a holistic understanding of data collection, management, processing, analysis and interpretation.

PSO 4. become proficient in the use of statistical software and writing program code to address complex statistical computations.

PSO 5. be able to design and present an original work of research at the leading edge of the statistics discipline.

PSO 6. be able to identify and articulate strategies for dealing with ethical issues that may arise.

PSO 7. attain mastery of broad-based knowledge in social work and specific knowledge relevant to their own research interests, including theories and methods of intervention.

PSO 8. be able to explain some elementary statistical courses independently

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Course Work for Ph. D. (Statistics) Program

Every student admitted for the Ph. D. program in Statistics will be required to pass a one semester (six months) course work of minimum 16 credits. The division of this 16 credits course work is as follows:

Course Code	**Course Title**	**Credits**
Compulsory Courses		
STAT 601	Research Methodology	4+0
Discipline-Specific Course(Compulsory)		
STAT 602	Statistical Theory	6+0
Research Theme- Specific Courses **Open Elective Course (*Any one of the following:*)**		
STAT 603	Demography and Applied Statistics	6+0
STAT 604	Bayesian Statistics and Reliability Theory	6+0
STAT 605	Operations Research and Numerical Methods	6+0
STAT 606	Statistical Computing with R	6+0
Research Project		Non Credit
Total		**16 Credits**

Note: The division of theory and internal marks of each paper will be decided by University (as per common ordinance for examination and assessment).

COURSE CONTENTS

Research Methodology

Course Code: STAT 601 **Credit: 4+0**

Objectives: This course is designed to enable students to

1. identify and discuss the issues and concepts salient to the research process.
2. identify and discuss the fundamental knowledge of basics of philosophy of science and ethics, research integrity, publication ethics.
3. identify and discuss the plagiarism tools for a valid and ethical research report.
4. the knowledge internet and its uses in research work.
5. familiar with the MS word, MS-Excel, Power Point and LaTex.

UNIT-I

Origin of Research, objectives of research, motivation and necessity of research, Steps in Research, types of research, research approaches, significance and relevance of research, conditions for good research and criteria of good research. What is Research Problem?, selection of research problem, choosing the research area, identification of research problem and solving research problems, role of a research supervisor. Statistical Heritage of India: contributions of Indian scholars.

UNIT-II

Literature review, review of published article and books in the field of research work undertaken, writing a synopsis, writing a research proposal, writing a research paper/article, chapter writing, writing a dissertation, writing a Ph.D. thesis, Review Articles, Proof reading, Keywords and Phrases, bibliography, referencing, Mathematical subject Classifications(MSC) and indexing, short communication, fast track communication of a research paper, Plagiarism prevention, Poster/Oral presentation of research papers, Plenary talks, Invited talks of a conference/ workshop.

UNIT-III

Ethical issues, ethics with respect to science and research, intellectual honesty and research integrity, copy right, intellectual property right and patent law, plagiarism, citation, indexing of journal, impact factor of journal, h-index, g-index, i10 index, google scholar and acknowledgement. Introduction and use of plagiarism software: Urkund, Turnitin and iThenticate.

UNIT-IV

Introduction of Internet, Email, MS-Word, MS-Excel, Power Point, LaTex and Beamer in research work. Introduction of at least one software out of the following: Mathematica /MATLAB / Maple / Scilab / Sage Math / R programming / Python. Introduction of Math SciNet, ISTOR and other online journals. Web Browsing for Research: Usage of Webs as a tool for scientific literature survey.

Suggested Readings:

1. Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. An introduction to Research Methodology, RBSA Publishers.
2. Kothari, C.R., 1990. Research Methodology: Methods and Techniques. New Age International, 418p.
3. Day, R.A., 1992. How to write and publish a Scientific paper, Cambridge University Press.
4. Fink, A.,2009. Conducting Research Literature Reviews: From the internet to paper. Sage Publications.
5. Satarkar, S.V.,2000. Intellectual property rights and copyright. EssEss Publications.
6. Saxena, V.P.,2013. Lecture Notes on Research Methodology. Indra Publishing House.
7. Beall, J. (2012) – Predatory publishers are corrupting open access. Nature, 489(7415).
8. P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865
9. P.K. Sinha & Priti Sinha, Computer Fundamentals, BPB Publications.
10. Dilip Datta, LaTeX in 24 Hours: A Practical Guide for Scientific Writing, Springer (2017).
11. Introduction to Information Technology, ITL Education Solutions, Pearson Education.
12. Introduction to Computer Science, ITL Education Solutions, Pearson Education.
13. George Grätzer, More Math IntoLaTeX, 4th Edition, Springer (2016).
14. Amos R. Omondi, Mark Ng'ang'a, and Ryan Marvin, Python Fundamentals: A Practical Guide for Learning Python, Complete with Real-world Projects for You to Explore, PAKCT Publishing (2019).
15. Trochim, W.M.K, Research Methods: The concise knowledge base, Atomic Dog Publication (2005).
16. Sinha, S.C. and Dhiman, A.K., Research Methodology, Ess Publication (2002).

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

CO 1. explain key research concepts and issues.

CO 2. have good understanding of publication ethics and scientific conduct.

CO 3. have awareness about indexing and citation databases, open access publications and various research metrics like citations, h-index, Impact Factor etc.

Discipline Specific Course

Statistical Theory

Course Code: STAT 602 **Credit: 6+0**

Objectives : *The main objective is to build the theoretical foundation of Statistical methodology : probability including probability distribution and statistical inference : Point Estimation, Testing of Hypothesis and the concept of Interval Estimation.*

Unit-I

Brief review of probability and distribution theory of uni-dimensional random variable. Multi-dimensional random variables (random vectors): Joint, marginal, and conditional distribution

functions; Independence; Moments and moment generating function; characteristic function, Conditional mean and conditional variance; Some examples of conditional expectations.

Unit-II

Discrete and absolutely continuous distributions; Bernoulli, binomial, geometric, negative binomial, hypergeometric, Poisson, uniform, exponential, gamma, Weibull, beta, Cauchy, log-normal, logistic, double exponential, normal. Multinomial and multivariate normal distributions. Distribution of functions of random variables including order statistics.

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Unit-III

Introduction to Parametric Models and Problems of Statistical Inference. Completeness and bounded completeness, Score function, Statistic(s), Sufficient statistics, factorization theorem (proof for discrete case only), Likelihood function and statistics, minimal sufficient statistics, Lehman-Scheffe criterion for obtaining minimal sufficient statistics, Completeness of sufficient statistics, Cramer Rao inequality for biased and unbiased estimators, Minimum variance unbiased estimation, necessary and sufficient condition, Rao-Blackwell and Lehman - Scheffe theorem, Properties of M.L.estimators.

Unit-IV

Testing hypothesis : Notion of hypothesis testing, critical function, size and power of a test, MP and UMP tests, Randomized and Non-randomized tests, Neyman-Pearson Lemma, Optimal test for simple hypothesis concerning one parameter. MLR property. Testing one sided composite in MLR models.

Confidence Estimation: Interval estimation for single unknown parameter, Confidence regions, Confidence bounds, Uniformly most accurate confidence intervals and uniformly most accurate unbiased confidence intervals, Correspondence between testing of hypothesis and confidence Interval estimation.

Suggested Readings:

1. Gupta, S.C. and Kapoor, V.K. : Fundamental of Mathematical Statistics.
2. Johnson, N. L., Kotz, S., & Balakrishnan, N. (1994). *Continuous Univariate Distributions-vol. 1 (2nd* ed.). New York: John Wiley and Sons.
3. Johnson, N. L., Kotz, S., & Balakrishnan, N. (1995). *Continuous Univariate Distributions- 2* (2nd ed.). New York: John Wiley and Sons.
4. Mukhopadhyay, N.: Probability and Statistics, Marcel Dekkar, Inc., NY, USA, 2000.
5. Rohatgi, V.K., Md. E. Saleh, A. K.: An Introduction to Probability and Statistics, John Wiley & Sons, 2011.
6. Casella, G., & Berger, R.(1990). *Statistical Inference*. Belmont: Duxbury Press.
7. Goon,Gupta,& Dasgupta :An Outline of Statistical Theory Vol-I,II,World press Pvt Ltd
8. Kale,B.K.(1999): A First Course on Parametric Inference, Narosa Publication House, New Delhi
9. Mood,A.M.,Graybill,F.A.& Boes,D.C. :Introduction to the Theory of Statistics, Tata McGraw Hill
10. Mukhopadhyay, N.: Probability and Statistics, Marcel Dekkar, Inc., NY, USA, 2000.
11. Rohatgi, V.K., Md. E. Saleh, A. K.: An Introduction to Probability and Statistics, John Wiley & Sons, 2011.
12. Zacks,S. Parametric Statistical Inference, Pargamon Press

Course Outcomes:

After successful completion of this course, student will know:

- **CO 1.** Standard Discrete and Continuous Distributions. Applications of various distributions.
- **CO 2.** Method of obtaining distributions of transformed variables
- **CO 3.** Inter relationships between typical random variables
- **CO 4.** Distributions of order statistics.
- **CO 5.** Basic concept in inference different estimation techniques used in statistics.
- **CO 6.** Methods of estimation and testing of hypothesis properties of a good estimator.
- **CO 7.** Cramer-Rao inequality, Rao-Blackwell and Lehmann–Scheffe theorems.
- **CO 8.** the concepts of MVBUE, MVUE, UMVUE.
- **CO 9.** construction of MP,UMP and Generalized Likelihood tests.
- **CO 10.** Interval Estimation.

Research Theme- Specific Courses

Demography and Applied Statistics

Course Code: STAT-603 **Credit: 6+0**

Objectives: *The main objective of this course is to describe current population trends, in terms of fertility, mortality and population growth and the concepts of Statistical Quality Control, Quality Assurance and Performance Analysis.*

Unit-I

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

Unit-II

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

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

Unit-III

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

Index Numbers : Introduction, Use of Index Number, Classification of Index Number, Problem in constructions of Index Number, Method of Constructing Index Numbers. Value Index Numbers,

Test of Adequacy of Index Numbers Formulas Chain Index Numbers Consume price Index Numbers of industrial Production.

Unit-IV

Time Series Analysis : Introduction ,Time Series Definitions Utility Of Time Series Analysis. Component Of Time Series, Measurement of Trend ,Seasonal variations, Cyclic Variations.

Statistical Quality Control : Introduction ,Control chart Shewhart Control Chart $\bar{X}$chart, R Chart Control Chart for C (number of defects per unit), Control Chart for P (Fraction of defective), Acceptance Sampling.

Suggested Readings:

1. Keyfitz, N. (1977) Applied Mathematical Demography John Wiley & Sons N.Y.
2. Cox P.R. (1976): Demography, Cambridge University Press.
3. Spiegelman, M. (1980) Introduction to Demography Harvard University Press
4. S.P.Gupta (2021):Statistical Method, Sultan Chand & Sons.
5. R. Ramakumar (1986): Technical Demography, Wiley Eastern limited.

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

CO 1. Identify principal sources of demographic data and assess their strengths and weaknesses,

CO 2. discuss the demographic significance of age structures and the implications of variations in age structure,

CO 3. specify and calculate the principal demographic measures, and standardize these measures for comparison and interpretation,

CO 4. identify the components of population change, including the effects of changing birth, death and migration rates, and demonstrate their influences on age structure,

CO 5. Measuring the effect of changes in price, quality, Value of the Measuring Commodities have today become one of the most undely in industrial production and in share market.

CO 6. Identify and analyse the component of economics and business flactuations these days is to make estimates for future.

CO 7. To Identify and analyse of strategy technique, become obsolutely necesory for a businessman and consumes to keep a continuous watch our the quqlity of good produce or purchase .

Bayesian Statistics and Reliability Theory

STAT-604 **Credit: 6+0**

Objectives: *The objective of this course is to provide the understanding of the fundamentals of Bayesian inference including concept of subjectivity and priors by examining some simple Bayesian models and linear regression in a Bayesian framework and to introduce different concepts and their interpretation in reliability and survival analysis.*

Unit-I

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

Natural Conjugate family of priors for a model. Conjugate families for (i) exponential family models, (ii) models admitting sufficient statistics of fixed dimension.. Non informative, improper and invariant priors.

Unit-II

Bayesian point estimation: as a prediction problem from posterior distribution. Bayes estimators for (i) absolute error loss (ii) squared error loss (iii) 0 – 1 loss. Generalization to convex loss functions. Evaluation of the estimate in terms of the posterior risk.

Bayesian interval estimation: Credible intervals. Highest posterior density regions. Bayesian testing of Hypothesis: Specification of the appropriate form of the prior distribution for a Bayesian testing of hypothesis problem. Bayes factor, Discussion of Lindley's paradox for testing a point hypothesis for normal mean against the two sided alternative hypothesis.

Unit-III

Bayesian prediction problem, Large sample approximations for the posterior distribution.

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

Preliminaries: Definition and concept of time, event, Reliability/Survival function, Quantiles, hazard rate, cumulative hazard function and their relation with survival function mean residual life.

Unit-IV

Parametric models: Exponential, Weibull and normal and their survival characteristics. Censoring mechanisms- type I, type II and left right and interval censoring. Likelihood function under censoring and related problems, Fitting parametric models to reliability/survival data with and without censoring. Introduction of Bayesian estimation for parametric models.

Empirical survival function, Actuarial estimator, Kaplan–Meier estimators and its properties.

Suggested Readings:

1. Berger, J.O. : Statistical Decision Theory and Bayesian Analysis, Springer Verlag.
2. Robert C.P. and Casella, G. : Monte Carlo Statistical Methods, Springer-Verlag.
3. Leonard T. and Hsu, J.S.J. : Bayesian Methods. Cambridge University Press.
4. DeGroot M.H. : Optimal Statistical Decisions. McGraw Hill.
5. Bernando J.M. and Smith, A.F.M. : Bayesian Theory, John Wiley and Sons.
6. Robert, C.P. :The Bayesian Choice : A Decision Theoretic Motivation, Springer Verlag.
7. Deshpande, J.V. and Purohit, S. G.(2005): Life Time Data: Statistical Model and Methods, World Scientific.
8. Cox, D. R. and Oakes, D. (1984): Analysis of Survival Data, Chapman and Hall, New York.
9. Sinha, S. K. and Kale, B. K. (1983): Life Testing and Reliability Estimation, Wiley Eastern Limited.
10. Elandt – Johnson, R.E. Johnson N. L.: Survival Models and Data Analysis, John Wiley and Sons.
11. Miller, R. G. (1981): Survival Analysis (John Wiley)

Course Outcomes:

After successful completion of this course, student will be able to:

CO 1. Treat "evidence" as value of observations and prescribe methods to deal rationally with it.

CO 2. Equip students with skills to carry out and interpret posterior and pre posterior data based modeling and analyses.

CO 3. Compute probability that the theory in question could produce the observed data.

CO 4. Examine some simple Bayesian models and linear regression in a Bayesian framework.

CO 5. Learning various statistical lifetime models.

CO 6. Understanding various classes and their interrelations.

CO 7. Non-parametric estimation in lifetime data.

Operations Research and Numerical Methods

STAT-605 **Credit : 6+0**

Objectives: *The main course objective of this course is to introduce basic concepts of optimization and computing theory for model formulation and effective decision–making.*

UNIT-I

Review of Linear optimization, linear programming, and basic concepts of optimization. Convex sets, Convex and concave functions, Theorems on convexity, Linear programming problem (LPP), Simple and general LPP, Canonical and standard forms of LPP. Solution of general LPP by Simplex method, Big-M method and Two-Phase method, Concept of duality in linear programming, Theorems on duality, Dual simplex method. Transportation problem, Solution of transportation problem, Assignment problem Solution of assignment.

UNIT-II

Non-Linear Programming: Introduction and definitions. Formulation of non-Linear programming

problems, General non-linear programming problems. Kuhn-Tucker conditions, Lagrangian Method, Constrained optimization with equality constraints. Constrained optimization with inequality constraints. Saddle point problems Saddle points and NLPP. Wolfe's and Beale's method to solve Quadratic Progamming problem.
Inventory Control: Introduction, Classification of Inventory, Economic parameter associated with inventory problems, Deterministic and Probabilistic models with and without lead time.

UNIT-III

Sequencing and Replacement Problems: Assumptions for sequencing problem. Processing n jobs on two machines,n jobs on three machines, 2 jobs on m machines, Problem of Replacement, Individuals and Group replacement policies.
Network Analysis: Basic concepts and definition. Network drawing and analysis Critical path method. Labelling method. Methods based on time estimates to find critical path. Concept of slack and float. Resource levelling and time-cost trade-off analysis. Time-cost optimization procedure, Project crashing. PERT, Differences in PERT and CPM. Shortest path model minimum spanning tree problems. Kruskal's and Prim's Algorithm**.**

UNIT-IV

Numerical Methods: Concept of function approximation, Principle of least squares. Fitting of curves reducible to polynomials by transformation. Interpolation with equal and unequal intervals, Newton's forward and backward interpolation formulae, Lagrange's interpolation formula, Numerical Integration by Trapezoidal and Simpson rules**.** Real roots of a numerical equation by bisection, Regula-Falsi, Newton-Raphson and iteration methods.

Suggested Readings:

1. Eric Matthes, Python Crash Course, William Polock 2016.
2. H.A. Taha: Operations Research – An Introduction, Macmillan Publishing Co., Inc.,
3. J.K. Sharma: Operations Research – Theory and Applications, Macmillan India Ltd.
4. M. K. Jain, S.R.K. Iyengar & R.K. Jain, Numerical Methods for Engineering and scientific computation. NewYork., Oxford University Press.
5. S. S. Sastry, Introductory methods of Numerical Analysis.
6. S.D. Sharma: Operations Research, Kedar Nath Ram Nath & Company.
7. S.S. Rao: Optimization Theory and Applications, Wiley Eastern Ltd., New Delhi.
8. Srimanta Pal (2009). Numerical Methods - Principles, Analysis and Algorithms.
9. Winston Wayne L., Operations Research: Applications and Algorithms, Cengage Learning, 4th Edition.

Course Outcomes:

After successful completion of this course, student will be able to:

- **CO 1.** understand the significance of optimization theory and computation in research.
- **CO 2.** identify and develop operations research models from the verbal description of the real system.
- **CO 3.** understand the characteristics of different types of decision-making environments and decision making approaches.
- **CO 4.** Understand the mathematical tools that are needed to solve optimization problems.
- **CO 5.** Analyze the inventory situations.
- **CO 6.** Understand discrete event simulation and decision analysis with inclusion of

modelling based on random events involving uncertainties.

CO 7. Conceptualise optimum event management through Network scheduling'

CO 8. understand computing tools and techniques for research work.

Statistical Computing with R

STAT-606 **Credit : 6+0**

Objectives: *The objective of this course is to provide the understanding of the fundamentals of stochastic simulation & Monte-Carlo studies. The course is designed to enhance the programming skills and working knowledge of available numerical and statistical software.*

Unit-I

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

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.

Vector matrix operations: matrix operations such as addition, subtraction, multiplication, rank, eigenvalues, matrix inverse, generalized inverse, solution of linear equations, matrix decompositions. Numerical integration. Solution of non-linear equations: Roots extraction using different methods. Numerical optimization.

Unit-II

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

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

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Unit-III

Maximum likelihood estimation : Solution of likelihood equations, computation of asymptotic confidence intervals. Percentile method of estimation. Smoothing with kernels: density estimation Model validation tools: Parametric models and their goodness of fit. Probability-Probability(PP) and Quantile-Quantile(QQ) plots.

Monte Carlo integration, importance sampling for integration. Monte Carlo methods in inference: simple problems on estimation. Bootstrap methods: resampling paradigms, bias and standard errors, confidence intervals.
EM algorithm: applications to missing and incomplete data problems, mixture models.

Unit-IV

Bayesian Computation: Elements of Bayesian inference, Bayesian point estimation: credible intervals; highest posterior density intervals, Markov chain Monte Carlo(MCMC) methods : Metropolis-Hastings, Gibbs and Metropolis with Gibbs algorithms for full conditional distributions, Issues in the implementation of MCMC. Convergence diagnostics. Output analysis: visual and numerical summary of MCMC samples, implementation in OpenBUGS/MultiBUGS.
Statistical modeling and Information criteria: Concept of statistical modeling, modeling methodology, Akaike information criterion(AIC), Bayesian information criterion(BIC), Deviance information criterion(DIC). Model fit and model complexity. Model comparison.
Introduction to basics of Machine learning.

Suggested Readings:

1. Efron, B. and Tibshirani, R.J.(1993): An Introduction to the Bootstrap, Chapman and Hall.
2. Fishman, G.S. (1996): Monte Carlo: Concepts, Algorithms, and Applications, Springer.
3. Gentle, J.E.(2003). Random Number Generation and Monte Carlo Methods, Springer.
4. Givens, G. and Hoeting, J. (2005). *Computational Statistics*, John Wiley.
5. Lunn, D.J., Jackson, C., Best, N., Andrew, A., & Spiegelhalter, D. (2013). *The BUGS Book :A Practical Introduction to Bayesian Analysis*. London, UK: Chapman & Hall/CRC.
6. Maindonald, J. H. and Braun, J. (2010): Data Analysis and Graphics Using R, 3rdEdition, Cambridge University Press.
7. McLachlan, G.J.,and Krishnan, T. The EM Algorithms and Extensions, John Wiley.
8. Michael J. C. (2015): Statistics: An Introduction Using R, 2nd Edition John Wiley and Sons.
9. Murdoch, D. J. and Braun, J. (2016): A First Course in Statistical Programming with R, 2nd Edition,Cambridge University Press, Cambridge.
10. Rizzo, M. L. (2008): Statistical Computing with R, Chapman & Hall/CRC.
11. Robert C.P .and Casella,G.(2004): Monte Carlo Statistical Methods, Springer Verlag.
12. Ross, S.M.(2012): Simulation, Fifth Edition, Academic Press.
13. Rubinstein, R.Y. and Kroese, D.P. (2008): Simulation and the Monte Carlo Method, John Wiley & Sons.
14. Spector, P. (2008): Data Manipulation with R, Springer, New York.
15. Zuur, A. F., Leno, E. N. and Meesters, E. H. W. G. (2009): A Beginner's Guide to R, Springer.

Course Outcomes:

The students will get acquainted with

CO 1. Statistical Computation using Software.

CO 2. R programming with some basic notions for developing their own simple programs and visualizing graphics in R.

CO 3. Generation of random variables from various distributions.
CO 4. Interactive computational & graphical techniques in model building
CO 5. Data based inference methods such as EM and Bootstrap
CO 6. Markov chain Monte Carlo methods.
CO 7. Bayesian Computation using Software