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Department of Statistics

B.Sc.(H), Statistics Semester-VII

Category I

DISCIPLINE-SPECIFIC CORE COURSE – 19: MULTIVARIATE ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Analysis	4	3	0	1	-	Knowledge of Probability Distributions and Statistical Inference.

Learning Objectives

The learning objectives include:

- To study Bivariate Normal Distribution along with their properties.
- To study Multivariate Normal Distribution with their properties alongwith its applications analysis.
- Concepts of Multiple and partial correlation coefficients along with their interpretation.
- Analysis of multivariate data using discriminant analysis, principal component analysis, factor analysis and cluster analysis.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- The understanding of Multiple and partial correlation coefficients.
- Analysis of multivariate data using dimension reduction techniques like principal component analysis, factor analysis and cluster analysis.
- The classificatory method namely discriminant analysis.

SYLLABUS OF DSC-19

Theory

UNIT 1

Bivariate Normal Distribution **(15 hours)**

Probability density function of Bivariate Normal Distribution (BVN). Moment generating function, marginal distribution, conditional distribution of BVN and properties of BVN. Introduction of random vector, probability mass function, probability density functions of random vector, distribution function, mean vector, dispersion matrix, marginal distributions and conditional distributions of random vector.

UNIT 2

Multivariate Normal distribution **(15 hours)**

Probability density function of Multivariate Normal distribution (MVN). Moment generating function, marginal and conditional distribution of MVN. Properties of MVN. Sampling distribution of sample mean vector and sample variance-covariance matrix. Regression planes. Multiple and partial correlation coefficients with their properties and interpretations.

UNIT 3

Multivariate Data Analysis **(15 hours)**

Dimension reduction techniques: Principal component analysis and its applications, factor analysis and its applications, cluster analysis and its applications.

Classification technique: Discriminant analysis and its applications.

PRACTICAL/LAB WORK: (30 HOURS)

List of Practical:

1. Bivariate Normal Distribution and its properties.
2. Mean vector and dispersion matrix of Multivariate Normal Distribution.
3. Marginal distributions of Multivariate Normal Distribution.
4. Conditional distributions of Multivariate Normal Distribution.
5. Regression plane.
6. Partial Correlation Coefficient.
7. Multiple Correlation Coefficient.
8. Principal Component Analysis.
9. Discriminant Analysis.
10. Factor Analysis.
11. Cluster Analysis

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, 3rd Ed., John Wiley& Sons.
- Johnson, R.A. and Wichern, D.W. (2007). Applied Multivariate Analysis, 6th Ed., Prentice Hall.
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005). An Outline of Statistical Theory, Volume II, World Press.
- Applied multivariate data analysis, second edition, Brian.S.Everett and Graham Dunn,Oxford University Press,2001

SUGGESTED READINGS:

- S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons, 2020.
- Kshirsagar, A.M. (1972). Multivariate Analysis, 1st Ed., Marcel Dekker.
- Muirhead, R.J. (1982). Aspects of Multivariate Statistical Theory, John Wiley.
- Arora, S.andBansi, L. (1968). New Mathematical Statistics, 1st Ed., Vanita Printers.
- Rao, C. R. (2000). Linear Statistical Inference, John Wiley & Sons.
- Approaching multivariate analysis -A practical introduction, second edition, Pat Dugard,JohnTodman and Harry Staines, Routledge,2010.
- An R and S-plus companion to multivariate analysis, Brian Everitt,Springer texts in Statistics,Springer,2004.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective Course for B.Sc. (H) Statistics Semester-VII

DISCIPLINE SPECIFIC CORE COURSE – 5A: FINANCIAL STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Financial Statistics	4	3	0	1	Class XII pass with Mathematics.	Basic knowledge of Stochastic processes, Calculus and Probability theory and Financial markets

Learning Objectives

The learning objectives include:

- To study the Financial Statistics which deals primary and secondary financial markets and the mathematical models used by these markets?
- To study the Stochastic Calculus, this is the study of infinitesimal changes in stochastic processes and the methods of dealing with such changes over time.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Primary financial markets and their products such as equity, bonds and cash deposits
- Secondary financial markets and their products such as futures, forwards and options (American and European)
- Stochastic calculus- Stochastic differentiation and integration
- Stochastic differential equations and methods of solving them
- Applications of stochastic differential equations in formulating models to price various secondary financial markets products.
- Hedging techniques

SYLLABUS OF DSE- 5a

Theory

UNIT I **(10 hours)**

Introduction to investment and markets, Cash flows. Net present value, Future value, Internal rate of return, criteria for project appraisal, Basic theory of interest, different interest rates and their relationships, discount rates, bonds-pricing and yields, yield curves, spot rates, spot rate curves, Zero-coupon bonds, perpetual bonds and discount bonds,

Introduction to derivatives, Tools Needed for Option Pricing: Forward contracts, spot price, forward price, future price, Call and put options, binary one period model

Pricing derivatives: Arbitrage relations and perfect financial markets, Pricing futures, Put call parity for European and American options, Relationship between strike price and option price.

UNIT II **(15 hours)**

Discrete Stochastic Processes- Binomial processes, General random walks, Geometric random walks, Binomial models, Trinomial models.

Continuous time processes – Brownian motion, Geometric Brownian motion, Wiener process;

Introduction to stochastic calculus: stochastic integration, stochastic differential equations and their solutions; Itô's lemma. Black-Scholes differential equation

UNIT III **(15 hours)**

Intrinsic of option markets:, Black-Scholes formula for European options, Implied volatility, Binomial Model for European options, Hedging portfolios: Delta, Gamma and Theta hedging.

Cox-Ross-Rubinstein approach to option pricing. Discrete dividends, Trinomial model for American options, pricing American options, put call parity for American options, relationship between American and European options.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Relationship between various interest rates
2. Present value and future value
3. Relationship between interest rates and discount rates
4. To compute NPV and to obtain IRR of the investments.
5. To compute bond price and yields
6. Determination of spot rate curve
7. To verify "no arbitrage" principle.
8. To price future / forward contracts
9. Simulation of continuous time stochastic processes
10. To price options using Black – Scholes formula.
11. Pricing of options using discrete time models.
12. Impact of dividend on option prices.
13. Call-put parity for European options.
14. Application of Greeks to hedge investment portfolios.
15. Pricing of American options
16. Put call parity for American options.

ESSENTIAL READINGS:

- David, G. L. (2015). *Investment Science*, Oxford University Press(South Asian edition)
- Franke, J., Hardle, W.K. and Hafner, C.M. (2011). *Statistics of Financial Markets: An Introduction*, 3rd Ed., Springer Publications
- John C. Hull and Sankarshan Basu (10th edition) Options, Future and other derivatives, Pearson Indian edition.

SUGGESTIVE READINGS:

- Ovidiu Calin (2015): *An informal introduction to stochastic calculus and its applications* , World Scientific
- Baxter, M., Rennie, A., & Rennie, A. J. (1996). Financial calculus: an introduction to derivative pricing. Cambridge university press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5B: ADVANCED DESIGN OF EXPERIMENTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Design of Experiments	4	3	0	1	Class XII pass with Mathematics	Basic Knowledge of Design of Experiments

Learning Objectives

The learning objectives include:

- To design and conduct experiments.
- To analyse and interpret data.
- To construct designs.
- To apply experimental design techniques in real world problems.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Application of ANOVA technique for two –way classification, fixed effect models with unequal number of observations per cell, Random effect models with one observation per cell and the concept of Mixed effects models.
- Design and analysis of incomplete block designs, understand the concepts of orthogonality, connectedness and balancing.
- Understand the concepts of finite fields and finite geometries and apply them in the construction of MOLS, balanced incomplete block designs.
- Apply techniques of Response surface methodology and appreciate the concepts of orthogonality, rotatability and blocking.
- Understand the concept of mixture experiments that are useful in our day to day life, food industry, chemical industry, pharmaceutical companies.

- Understand and apply Crossover designs in practical situations.

SYLLABUS OF DSE-5b

Theory

UNIT I **(6 hours)**

Analysis of Variance

Fixed effect models (2-way classification with unequal number of observations per cell), Random effect models (2-way classification with one observation per cell) and the concept of Mixed effect models.

UNIT II **(12 hours)**

Incomplete Block Designs

Concepts of Connectedness, Orthogonality and Balance. Intrablock analysis of General Incomplete Block design. B.I.B designs with and without recovery of interblock information.

UNIT III **(13 hours)**

Finite fields

Finite Geometries- Projective geometry and Euclidean geometry. Construction of complete set of mutually orthogonal latin squares. Construction of B.I.B.D. using finite Abelian groups, MOLS, finite geometry and method of differences.

UNIT IV **(14 hours)**

Some Useful Designs

Response surface designs for first and second order models, concepts of orthogonality, rotatability and blocking. Mixture Experiments–models and designs, Cross-over designs

PRACTICAL/LAB. WORK (30 HOURS)

List of Practical:

1. Based on ANOVA for 2-way classification with unequal number of observations per cell under fixed effects model
2. Based on ANOVA 2-way classification with one observation per cell under random effects model
3. Based on ANOVA 2-way classification with one observation per cell under mixed effects model
4. Based on Intrablock analysis of an IBD
5. Based on analysis of a BIBD with and without interblock analysis.
6. Based on response designs for first and second order models.
7. Based on mixture designs,
8. Based on Cross-over designs.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (1980). An Outline of Statistical Theory, Vol 2, The world Press Private Limited.
- Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments, Wiley Eastern Limited.
- Dey, A. (1986). Theory of Block Designs, John Wiley & Sons.
- Hinkelmann, K. and Kempthorne, O. (2005). Design and Analysis of Experiments, Vol. 2: Advanced Experimental Design, John Wiley & Sons.
- Bose, M. and Dey, A. (2009). Optimal Crossover Designs, World Scientific.
- Cornell, John A. (2002). Experiments with Mixtures, John Wiley & Sons.
- Myers, R. H. and Montgomery, D. C. (2002). Response Surface Methodology: Process
- and Product Optimization using Designed Experiments, John Wiley & Sons.

SUGGESTED READINGS

- Chakrabarti, M.C. (1962). Mathematics of Design and Analysis of Experiments, Asia Publishing House, Bombay.
- Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. First Indian Reprint 2006.
- John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan Co., New York.
- Kshirsagar, A.M. (1983). A Course in Linear Models, Marcel Dekker, Inc., N.Y.
- Montgomery, D. C. (2005). Design and Analysis of Experiments, 6th ed., John Wiley & Sons.
- Raghavarao, D. and Padgett, L. V. (2005). Block Designs: Analysis, Combinatorics, and Applications, World Scientific.
- Raghavarao, D. (1970). Construction and Combinatorial Problems in Design of Experiments, John Wiley & Sons.
- Wu, C. F. J. and Hamada, M. (2000). Experiments: Planning, Analysis and Parameter Design Optimization, John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE –5C : ADVANCED THEORY OF BIOSTATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced theory of Biostatistics	**4**	**3**	0	**1**	Studied Biostatistics	Basic knowledge of survival analysis and survival models

Learning objectives:

The learning objectives include:

- Comparison of Survival in two groups
- Epidemiological Study and epidemic models.
- Independent and dependent risks in Competing risk theory.
- Concept of Relative Risk, Odds Ratio and Attributable Risk.
- Concept of Clinical trials.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Different methods for comparing survival rates of two groups of patients.
- Concept of Prospective, Retrospective and cross-sectional studies. Different epidemic models.
- Distinction between Relative Risk, Odds Ratio and Attributable Risk and their confidence interval.
- Different phases of clinical trials.

SYLLABUS OF DSE – 5c

Theory

UNIT I **(11 hours)**

Comparison of Survival in two groups:

Log-rank test, Gehan's generalized Wilcoxon test, Cox-Mantel test, Mantel-Haenszel Test, Comparison of two exponential survival distributions: Likelihood ratio test, Cox's F-test,
Concept of covariates and proportional hazard, Cox's proportional hazard model.

UNIT II **(12 hours)**

Epidemiological Study:

Prospective study, Retrospective study, cross-sectional study and their comparison. Sensitivity, specificity and predictivity of medical tests. Likelihood ratio of a positive and negative test result.
Epidemic Model: Concept of epidemic and epidemic models, Simple Stochastic Epidemic model (including derivations), Duration of an epidemic. General epidemic model & Carrier-borne epidemic model (concept and definition only)

UNIT III **(16 hours)**

Competing Risk Theory:

Concept of Competing risk theory with independent and dependent risks. Bivariate Normal dependent risk model and its derivations.
Concept of risk, hazard and odds, definition of relative risk (RR), relative risks in independent sample, attributable risk in independent samples, definition of odds ratio (OR), odds ratio in two independent samples, confidence interval and test of hypothesis for relative risk and odds ratio (independent samples)

UNIT IV **(6 hours)**

Clinical Trials:

Planning and designing clinical trials, Phase-I, Phase-II and Phase-III clinical trials. Single, double and triple blinding.

PRACTICAL/LAB WORK (30 HOURS)

List of Practicals:

1. Comparison of survival of two groups using Log-rank test.
2. Comparison of survival of two groups using Gehan's generalized Wilcoxon test.
3. Comparison of survival of two groups using Cox-Mantel test.
4. Comparison of survival of two groups using Mantel-Haenszel test.
5. Comparison of survival of two groups using Likelihood ratio test.
6. Comparison of survival of two groups using Cox's F-test.
7. Computation of Sensitivity and specificity of a medical test.
8. Computation of likelihood ratio of a medical test.
9. Computation of positive and negative predictivities and hence predictive validity of a medical test.
10. Calculation of relative risk and it's confidence interval.
11. Calculation of odds ratio and it's confidence interval.
12. Calculation of attributable risk and it's confidence interval.
13. Calculation of probability of r susceptible getting infected by time t.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Biswas, S. (2007): Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2nd Ed., New Central Book Agency.
- Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival data Analysis, 3rd Ed., John Wiley & Sons.
- Indrayan, A. (2008): Medical Biostatistics, 2nd Ed., Chapman and Hall/CRC.

SUGGESTED READINGS:

- Miller, R. G. (2011): Survival Analysis. John Wiley & Sons.
- Elandt-Johnson R.C (1971): Probability model and Statistical Methods in Medical Biostatistics, 2nd Ed., Chapman and Hall/CRC. Genetics, John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5D: RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of

- Research Methods.
- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 5d

Theory

UNIT I **(09 hours)**

Introduction to Research:
Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II **(09 hours)**
Methods & Techniques of Data Collection:
Survey methodology and Data collection, Source of data collection-Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III **(15 hours)**
Data Processing & Analysis:
Data processing, Exploratory data analysis, Review of various techniques (Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques) for data analysis covered in core statistics papers, Techniques of interpretation, Precaution in interpretation.
Report writing: Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

UNIT IV **(12 hours)**
Computer Application:
Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines.
Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.

PRACTICAL/LAB WORK – (30 hours)
PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2015): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.
- Anderson, J., Durston, B.H., Pooole, M. (1970): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2008): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2012): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics.

SUGGESTIVE READINGS

- Pannerselvan, R. (2006): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.

- Dalgaard, P. (2008): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2004): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (1998): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Category II

B.A.(Prog) with Statistics as Non-Major/Major Semester-VII

DISCIPLINE SPECIFIC CORE COURSE–7: STOCHASTIC PROCESSES AND QUEUEING THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Processes and Queueing Theory	4	3	0	1		Basic knowledge of Probability theory and Probability distributions

Learning Objectives:

The learning objectives include:

- To understand the concept of stochastic process and markov chain.
- To analyze the queueing models with applications;
- To identify the real life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Stability of Markov chains.
- Poisson process and its variations.
- Queuing systems.
- Random walk and ruin theory.

SYLLABUS OF DSC-7

Theory

UNIT I

Probability Generating Function **(12 Hours)**

Probability Distributions: Generating functions, Bivariate probability generating functions.

Stochastic Process: Introduction, Stationary Process.

UNIT II

Markov Chain (18 Hours)

Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Classification of states and chains, stability of Markov system. Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

UNIT III

Poisson Process and Queuing theory (15 Hours)

Postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process. Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).

PRACTICAL/ LAB WORK – (30 hours)

List of Practical:

1. Problems based on probability generating function to compute exact and approximate probabilities using partial fraction theorem.
2. Problems based on (covariance) stationary processes.
3. Markov Chains:
   a) Simulation of Markov chains and Calculation of transition probability matrices.
   b) Stability of Markov chains.
   c) To check whether the given chain is irreducible or not.
4. Simulation and applications of Poisson processes.
5. Calculation of probabilities for given birth and death processes.
6. Calculation of probabilities for ruin problems.
7. Problems based on (M/M/1) queuing models.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Medhi, J. (2009). Stochastic Processes, New Age International Publishers.
- Gross, Donald and Harris, Carl M (2008) Fundamentals of Queueing Theory, 4th Edition, Wiley International.
- Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol I, 3rd Ed., Wiley International.

SUGGESTED READINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- Bhat, B.R.(2000).Stochastic Models: Analysis and Applications, New Age International Publishers.
- Taha, H. (1995). Operations Research: An Introduction, Prentice- Hall India.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective Course

Discipline Specific Elective Course for B.A.(Prog) Semester-VII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5A: LINEAR PROGRAMMING TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming Techniques	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include:

- Concept of mathematical formulation to a real-life problem through Linear Programming.
- This course develops the ideas underlying the Simplex Method for Linear Programming Problem.
- The course covers Linear Programming with applications to Transportation and Assignment problem. Such problems arise in manufacturing, resource planning and financial sectors.

Learning Outcomes:

After completing this course, students will possess skills concerning:

- Learn about the graphical solution of linear programming problem with two variables.
- Learn about the relation between basic feasible solutions and extreme points.
- Understand the theory of the simplex method used to solve linear programmingproblems.
- Learn about two-phase and Big-M methods to deal with problems involving artificial variables
- Solve transportation and assignment problems.

SYLLABUS OF DSE – 5a

Theory

Unit I: **(14 Hours)**

Introduction to Linear Programming:

Linear programming problem**:** Standard, Canonical and matrix forms, Formulation of Linear Programming Problem, Graphical solution; Basic solutions, Basic feasible solutions.

Unit II: **(16 Hours)**

Methods of Solving Linear Programming Problem:

Simplex method**:** Optimal solution, Termination criteria for optimal solution of the linear programming problem, Unique and alternate optimal solutions, Unboundedness; Artificial variables, Two-phase method, Big-M method.

Unit III: **(15 Hours)**

Transportation and Assignment Problems:

Transportation Problem**:** Definition and formulation; Methods of finding initial basic feasible solutions; Northwest-corner rule. Least- cost method; Vogel's approximation method; Algorithm for solving transportation problem.

Assignment Problem**:** Mathematical formulation and Hungarian method of solving Assignment problem.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Graphical representation of Linear Programming Problem and its solution.
2. Graphical identification of basic solutions, basic feasible solution and optimal solution.
3. Solution of Linear Programming Problem by Simplex method.
4. Solution of Linear Programming Problem by Big-M method.
5. Solution of Transportation Problem as a Linear Programming Problem.
6. Solution of Assignment Problem as a Linear Programming Problem.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Reading:

- Hadley, G. (2002). Linear Programming. Narosa Publishing House. New Delhi.
- Taha, H. A. (2010). Operations Research. An Introduction, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). Operations Research, 15th Ed, Sultan Chand & Sons.

Suggested Readings:

- Hillier, Frederick S. & Lieberman, Gerald J. (2015). Introduction to OperationsResearch (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
- Sharma, J. K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE-5B: INTRODUCTION TO STATISTICAL LINEAR MODELS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorials	practical		
Introduction to Statistical Linear Models	4	3	0	1		Basic knowledge of Matrix theory and Probability distributions

Learning Objectives:

Learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics.

SYLLABUS OF DSC-14

THEORY

UNIT I **(12 Hours)**

Introduction

Statistical Linear Models and their classification, Estimability of linear parametric functions, Gauss-Markov setup, Normal equations and Gauss-Markov theorem, full rank case and non-full rank case (without proof)

UNIT II **(8 Hours)**

Distribution of quadratic forms

Cochran's theorem (without proof), Necessary and sufficient conditions for the mutual independence of quadratic forms and for the mutual independence of a linear function and a quadratic form.

UNIT III **(13 Hours)**

Regression analysis:

Simple and Multiple linear regression: Estimation of parameters and testing of hypotheses, Confidence intervals, Bias in regression estimates Lack of fit and pure error, Residuals and their plot. Techniques for variable selection. Polynomial Regression models: Orthogonal Polynomials.

UNIT IV **(12 Hours)**

Analysis of Variance:

Technique of analysis of variance (ANOVA) in one-way and two-way classifications with an equal number of observations per cell under fixed effect model.

PRACTICAL/LABWORK -30 Hours

List of Practical:

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Linear Regression
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Orthogonal Polynomials.
10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings

- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

Suggestive Readings:

- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(1993): Linear Algebra and Linear Models, Hindustan Book Agency.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE –5C: STATISTICAL METHODS IN PSYCHOLOGY AND EDUCATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Methods in Psychology and Education	4	3	0	1	Class XII pass with Mathematics	Knowledge of basic statistics and probability distributions

Learning Objectives:

The learning objectives include:
- To measure psychological traits and mental abilities
- To learn basic methods of test construction, item writing and item analysis
- To check the reliability and validity of test scores.

Learning Outcomes:

After successful completion of this course, students should be able to:
- Distinguish between Psychological measurement and physical measurement.
- Understand the meaning of Tests in Psychology and Education.
- Appreciate the uses and limitations of Psychological tests.
- Learn the meaning and purpose of Item writing and analysis.
- Understand concepts of reliability and validity of test scores and their differences.
- Convert raw scores into different transformed scores.
- Apply Scaling rankings and ratings in terms of the Normal Probability Curve.

SYLLABUS OF DSC-5c

Theory

Unit 1: **(15 Hours)**

Importance of statistics in psychology and education.

Importance of statistics in psychology and education. Levels of measurement: nominal ordinal interval and ratio scales. Distinction between psychological and physical measurements. General problems and sources of errors in measurements.

Meaning and types of tests in psychology and education. History of psychological measurement and testing. Uses and limitations of tests. Varieties of tests. Characteristics of a good test. General steps of test construction. Test administration and scoring.

Item writing and item analysis: Meaning and types of test items, Purpose and methods for evaluating test items.

Unit 2: **(15 Hours)**

Reliability and Validity:
Reliability: definition Methods of determining reliability: Test-retest, Alternate or parallel forms, Split half technique, Rational equivalence. Effect upon reliability of lengthening or repeating or test. Reliability coefficient as a measure of true variance. Estimating true scores by way of regression equation and reliability coefficient. Index of reliability.
Validity: meaning; Estimation of validity; Types of validity: validity and test length; comparison between reliability and validity.

Unit 3: **(15 Hours)**
Test Scores:
Meaning and differences between norm referencing and criterion referencing.
Raw score transformations- percentile scores, standard score, normalised standard scores, T- scores and Stanine scores.
Intelligence: definition. Types of intelligence test scores. Psychological scaling methods- scaling of individual test items in terms of difficulty, scaling of rankings and ratings in terms of the normal probability curve.

PRACTICAL LAB WORK (30 hours)
List of Practical:

1. Computation of reliability by Rulon and Kuder Richardson formulas.
2. Computing reliability of a test whose length is increased/decreased.
3. Computing index of reliability standard error of measurement.
4. Computing validity oblique maximum validity then test length is increased.
5. Computing relative difficulty of questions difference in difficulty between different tests.
6. Problem based on Z scores.
7. Problem based on t scores.
8. Problem based on Stanine scales.
9. Problem based on percentile scores.
10. Computing numerical scores corresponding to grades or ratings.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anastasia, A. and Urbina, S. (1997) Psychological testing (7th edition), Prentice Hall
- Garrett H.E. (2021), Statistics in Psychology and Education. Nation press.
- Gregory RJ (2016), Psychological testing: History, Principles and Applications. (updated 7th edition) Pearson
- Singh, A.K. (2006)Test, Measurements and Research in Behavioural Sciences Bharati bhavan
- Mangal S.K. (2016) Statistics in Psychology and Education. PHI learning Pvt ltd.

SUGGESTED READINGS:

- Gupta S.C. and Kapoor V.K. (2019) Fundamentals of Applied statistics, Sultan Chand and sons.
- Goon A.M., Gupta M.K. and Dasgupta, B. (2001) Fundamental of Statistics, Volume 2, World Press Pvt ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5D: RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of

- Research Methods.
- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 5d

Theory

UNIT I **(09 hours)**

Introduction to Research:

Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II **(09 hours)**

Methods & Techniques of Data Collection:

Survey methodology and Data collection, Source of data collection-Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III **(15 hours)**

Data Processing & Analysis: Data processing, Exploratory data analysis, Review of various techniques (Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques) for data analysis covered in core statistics papers, Techniques of interpretation, Precaution in interpretation.

Report writing: Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

UNIT IV **(12 hours)**

Computer Application:

Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines. Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.

PRACTICAL/LAB WORK – (30 hours)

PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2015): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.
- Anderson, J., Durston, B.H., Pooole, M. (1970): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2008): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2012): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics.

SUGGESTIVE READINGS

- Pannerselvan, R. (2006): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2008): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2004): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (1998): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Category III

B.Sc. (Prog) Mathematical Sciences with Statistics Semester-VII

DISCIPLINE SPECIFIC CORE COURSE–7: STOCHASTIC PROCESSES AND QUEUEING THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Processes and Queueing Theory	4	3	0	1		Basic knowledge of Probability theory and Probability distributions

Learning Objectives:

The learning objectives include:

- To understand the concept of stochastic process and markov chain.
- To analyze the queueing models with applications;
- To identify the real life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Stability of Markov chains.
- Poisson process and its variations.
- Queuing systems.
- Random walk and ruin theory.

SYLLABUS OF DSC-7

Theory

UNIT I

Probability Generating Function **(12 Hours)**

Probability Distributions: Generating functions, Bivariate probability generating functions. Stochastic Process: Introduction, Stationary Process.

UNIT II

Markov Chain **(18 Hours)**

Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities. Classification of states and chains, stability of Markov system. Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

UNIT III

Poisson Process and Queuing theory **(15 Hours)**

Postulates of Poisson process, properties of Poisson process, inter-arrival time, pure birth process, Yule Furry process, birth and death process. Queuing System: General concept, steady state distribution, queuing model, M/M/1 with finite and infinite system capacity, waiting time distribution (without proof).

PRACTICAL/ LAB WORK – (30 hours)

List of Practical:

1. Problems based on probability generating function to compute exact and approximate probabilities using partial fraction theorem.
2. Problems based on (covariance) stationary processes.
3. Markov Chains:
   d) Simulation of Markov chains and Calculation of transition probability matrices.
   e) Stability of Markov chains.
   f) To check whether the given chain is irreducible or not.
4. Simulation and applications of Poisson processes.
5. Calculation of probabilities for given birth and death processes.
6. Calculation of probabilities for ruin problems.
7. Problems based on (M/M/1) queuing models.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Medhi, J. (2009). Stochastic Processes, New Age International Publishers.
- Gross, Donald and Harris, Carl M (2008) Fundamentals of Queueing Theory, 4th Edition, Wiley International.
- Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol I, 3rdEd., Wiley International.

SUGGESTED READINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- Bhat, B.R.(2000).Stochastic Models: Analysis and Applications, New Age International Publishers.
- Taha, H. (1995). Operations Research: An Introduction, Prentice- Hall India.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective Course

Discipline Specific Elective Course for B.Sc. (Prog) Mathematical Sciences Semester-VII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5A: LINEAR PROGRAMMING TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming Techniques	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include:

- Concept of mathematical formulation to a real-life problem through Linear Programming.
- This course develops the ideas underlying the Simplex Method for Linear Programming Problem.
- The course covers Linear Programming with applications to Transportation and Assignment problem. Such problems arise in manufacturing, resource planning and financial sectors.

Learning Outcomes:

After completing this course, students will possess skills concerning:

- Learn about the graphical solution of linear programming problem with two variables.
- Learn about the relation between basic feasible solutions and extreme points.
- Understand the theory of the simplex method used to solve linear programmingproblems.
- Learn about two-phase and Big-M methods to deal with problems involving artificial variables
- Solve transportation and assignment problems.

SYLLABUS OF DSE – 5a

Theory

Unit I: **(14 Hours)**

Introduction to Linear Programming:

Linear programming problem**:** Standard, Canonical and matrix forms, Formulation of Linear

Programming Problem, Graphical solution; Basic solutions, Basic feasible solutions.

Unit II: (16 Hours)

Methods of Solving Linear Programming Problem:

Simplex method**:** Optimal solution, Termination criteria for optimal solution of the linear programming problem, Unique and alternate optimal solutions, Unboundedness; Artificial variables, Two-phase method, Big-M method.

Unit III: (15 Hours)

Transportation and Assignment Problems:

Transportation Problem**:** Definition and formulation; Methods of finding initial basic feasible solutions; Northwest-corner rule. Least- cost method; Vogel's approximation method; Algorithm for solving transportation problem.

Assignment Problem**:** Mathematical formulation and Hungarian method of solving Assignment problem.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

7. Graphical representation of Linear Programming Problem and its solution.
8. Graphical identification of basic solutions, basic feasible solution and optimal solution.
9. Solution of Linear Programming Problem by Simplex method.
10. Solution of Linear Programming Problem by Big-M method.
11. Solution of Transportation Problem as a Linear Programming Problem.
12. Solution of Assignment Problem as a Linear Programming Problem.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Reading:

- Hadley, G. (2002). Linear Programming. Narosa Publishing House. New Delhi.
- Taha, H. A. (2010). Operations Research. An Introduction, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). Operations Research, 15th Ed, Sultan Chand & Sons.

Suggested Readings:

- Hillier, Frederick S. & Lieberman, Gerald J. (2015). Introduction to OperationsResearch (10th ed.). McGraw-Hill Education (India) Pvt. Ltd.
- Sharma, J. K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE-5B: INTRODUCTION TO STATISTICAL LINEAR MODELS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorials	practical		
Introduction to Statistical Linear Models	4	3	0	1		Basic knowledge of Matrix theory and Probability distributions

Learning Objectives:

Learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics.

SYLLABUS OF DSC-14

THEORY

UNIT I **(12 Hours)**

Introduction

Statistical Linear Models and their classification, Estimability of linear parametric functions, Gauss-Markov setup, Normal equations and Gauss-Markov theorem, full rank case and non-full rank case (without proof)

UNIT II **(8 Hours)**

Distribution of quadratic forms

Cochran's theorem (without proof), Necessary and sufficient conditions for the mutual independence of quadratic forms and for the mutual independence of a linear function and a quadratic form.

UNIT III **(13 Hours)**

Regression analysis:

Simple and Multiple linear regression: Estimation of parameters and testing of hypotheses, Confidence intervals, Bias in regression estimates Lack of fit and pure error, Residuals and their plot. Techniques for variable selection. Polynomial Regression models: Orthogonal Polynomials.

UNIT IV **(12 Hours)**

Analysis of Variance:

Technique of analysis of variance (ANOVA) in one-way and two-way classifications with an equal number of observations per cell under fixed effect model.

PRACTICAL/LABWORK -30 Hours

List of Practical:

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Linear Regression
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Orthogonal Polynomials.
10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings

- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

Suggestive Readings:

- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(1993): Linear Algebra and Linear Models, Hindustan Book Agency.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE –5C: STATISTICAL METHODS IN PSYCHOLOGY AND EDUCATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Methods in Psychology and Education	4	3	0	1	Class XII pass with Mathematics	Knowledge of basic statistics and probability distributions

Learning Objectives:

The learning objectives include:
- To measure psychological traits and mental abilities
- To learn basic methods of test construction, item writing and item analysis
- To check the reliability and validity of test scores.

Learning Outcomes:

After successful completion of this course, students should be able to:
- Distinguish between Psychological measurement and physical measurement.
- Understand the meaning of Tests in Psychology and Education.
- Appreciate the uses and limitations of Psychological tests.
- Learn the meaning and purpose of Item writing and analysis.
- Understand concepts of reliability and validity of test scores and their differences.
- Convert raw scores into different transformed scores.
- Apply Scaling rankings and ratings in terms of the Normal Probability Curve.

SYLLABUS OF DSC-5c

Theory

Unit 1: **(15 Hours)**

Importance of statistics in psychology and education.

Importance of statistics in psychology and education. Levels of measurement: nominal ordinal interval and ratio scales. Distinction between psychological and physical measurements. General problems and sources of errors in measurements.

Meaning and types of tests in psychology and education. History of psychological measurement and testing. Uses and limitations of tests. Varieties of tests. Characteristics of a good test. General steps of test construction. Test administration and scoring.

Item writing and item analysis: Meaning and types of test items, Purpose and methods for evaluating test items.

Unit 2: **(15 Hours)**

Reliability and Validity:
Reliability: definition Methods of determining reliability: Test-retest, Alternate or parallel forms, Split half technique, Rational equivalence. Effect upon reliability of lengthening or repeating or test. Reliability coefficient as a measure of true variance. Estimating true scores by way of regression equation and reliability coefficient. Index of reliability.
Validity: meaning; Estimation of validity; Types of validity: validity and test length; comparison between reliability and validity.

Unit 3: **(15 Hours)**
Test Scores:
Meaning and differences between norm referencing and criterion referencing.
Raw score transformations- percentile scores, standard score, normalised standard scores, T- scores and Stanine scores.
Intelligence: definition. Types of intelligence test scores. Psychological scaling methods- scaling of individual test items in terms of difficulty, scaling of rankings and ratings in terms of the normal probability curve.

PRACTICAL LAB WORK (30 hours)
List of Practical:
1. Computation of reliability by Rulon and Kuder Richardson formulas.
2. Computing reliability of a test whose length is increased/decreased.
3. Computing index of reliability standard error of measurement.
4. Computing validity oblique maximum validity then test length is increased.
5. Computing relative difficulty of questions difference in difficulty between different tests.
6. Problem based on Z scores.
7. Problem based on t scores.
8. Problem based on Stanine scales.
9. Problem based on percentile scores.
10. Computing numerical scores corresponding to grades or ratings.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anastasia, A. and Urbina, S. (1997) Psychological testing (7th edition), Prentice Hall
- Garrett H.E. (2021), Statistics in Psychology and Education. Nation press.
- Gregory RJ (2016), Psychological testing: History, Principles and Applications. (updated 7th edition) Pearson
- Singh, A.K. (2006)Test, Measurements and Research in Behavioural Sciences Bharati bhavan
- Mangal S.K. (2016) Statistics in Psychology and Education. PHI learning Pvt ltd.

SUGGESTED READINGS:

- Gupta S.C. and Kapoor V.K. (2019) Fundamentals of Applied statistics, Sultan Chand and sons.
- Goon A.M., Gupta M.K. and Dasgupta, B. (2001) Fundamental of Statistics, Volume 2, World Press Pvt ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 5D: RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of

- Research Methods.
- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 5d

Theory

UNIT I **(09 hours)**

Introduction to Research:

Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II **(09 hours)**

Methods & Techniques of Data Collection:

Survey methodology and Data collection, Source of data collection-Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III **(15 hours)**

Data Processing & Analysis: Data processing, Exploratory data analysis, Review of various techniques (Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques) for data analysis covered in core statistics papers, Techniques of interpretation, Precaution in interpretation.

Report writing: Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

UNIT IV **(12 hours)**

Computer Application:

Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines. Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.

PRACTICAL/LAB WORK – (30 hours)

PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2015): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.
- Anderson, J., Durston, B.H., Pooole, M. (1970): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2008): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2012): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics.

SUGGESTIVE READINGS

- Pannerselvan, R. (2006): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2008): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2004): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (1998): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY DEPARTMENT OF STATISTICS (Semester-VII)

Category VI

GENERAL ELECTIVE COURSE – 7A: NONPARAMETRIC METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nonparametric Methods	4	3	0	1	Class XII pass with Mathematics	Knowledge of hypothesis testing

Learning Objectives

The learning objectives include:

- Utility of Nonparametric/distribution free tests and its role for different type of data
- Quantile and Empirical distributions and their utility
- Test for randomness, location and scales under nonparametric setup
- Test association of bivariate samples

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Distinguish between parametric and nonparametric test and appreciate different measurement scales.
- Understands quantile and empirical distribution function and its utility.
- Use nonparametric test for both one/two samples problem, Test for randomness, Kolmogorov- Smirnov one sample and two sample tests, sign test, Wilcoxon signed rank test, run test. Median test, Mann Whitney U test, Kruskal-Wallis one-way analysis of variance by ranks.
- Test association of bivariate samples using Kendall Tau and Spearman's rank correlation.

SYLLABUS OF GE-7A

Theory

UNIT I **(15 hours)**

Nonparametric Tests:

Introduction and Concept, Non-parametric tests-their advantages and disadvantages, comparison with parametric tests. Measurement scale-nominal, ordinal, interval and ratio. The quantile function, the empirical distribution function, Test for randomness based on total number of runs.

UNIT II **(15 hours)**

One-Sample, two-sample problem, and Paired-Sample Procedures: the sign test, treatment of ties in rank tests, Wilcoxon signed-rank test, Wald-Wolfowitz runs test, Kolmogorov-Smirnov one and two-sample test, median test, and the Mann-Whitney U test.

UNIT III **(15 hours)**

Linear Rank Tests for the Location and Scale Problem:

Definition of linear rank statistics, Wilcoxon rank-sum test; Tests of the Equality of k Independent Samples: The Kruskal-Wallis one-way ANOVA test; Measures of Association for Bivariate Samples: definition of measures of association in a bivariate population, Kendall's Tau coefficient, Spearman's coefficient of rank correlation.

PRACTICAL/LABWORK(30 hours):

List of Practical

1. Obtaining quantile and Empirical Distribution
2. Test for randomness
3. Sign test
4. Wilcoxon Signed rank test
5. Wald-Wolfowitz runs test,
6. Kolmogorov-Smirnov one sample test,
7. median test and the Mann-Whitney U test.
8. Wilcoxon rank-sum test
9. The Kruskal-Wallis one-way ANOVA test
10. Test based on Kendall's Tau coefficient.
11. Spearman's coefficient of rank correlation

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gibbons, J. D., and Chakraborti, S. (2020): Nonparametric statistical inference. CRC press.
- Siegel, S. (1956). Nonparametric statistics for the behavioral sciences. McGraw-Hill.

SUGGESTIVE READINGS:

- Kloke, J., and McKean, J. W. (2014) : Nonparametric statistical methods using R. CRC Press.
- Hollander, M., Wolfe, D. A., and Chicken, E. (2013): Nonparametric statistical methods (Vol. 751). John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERAL ELECTIVE COURSE – 7B: INTRODUCTION TO BAYESIAN INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction To Bayesian Inference	4	3	0	1	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives:

The learning objectives of this course is

- To introduce students to the Bayesian approach to statistics
- To make students understand the basic difference between the commonly-taught
- Frequentist approach and the Bayesian Paradigm.
- To demonstrate the benefits of using a Bayesian approach and obtaining results that are
- more interpretable

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Bayes theorem for random variables
- Prior and posterior distributions
- Conjugate prior
- Non-informative priors
- Bayesian point estimation
- Bayesian Credible intervals
- Bayes factor

SYLLABUS OF GE-7b

Theory

UNIT I: **(5 Hours)**

Bayes Theorem for Random Variables

Revision of some basic distributions; Bayes theorem for events; Bayes theorem for random variables; Concept of likelihood function, prior distribution and posterior distribution.

UNIT II: **(12 Hours)**

Conjugate Prior and Non-Informative Priors

Thumb rule for constructing a conjugate prior; Conjugate families for samples from various standard distributions: Uniform prior; Jeffreys' non-informative priors.

UNIT III: **(15 Hours)**

Bayes Estimation and Credible Interval

Elements of Bayes Decision Theory; Loss Functions; Squared error loss function; Bayes risk; Normal and Extensive form of analysis; Bayesian credible intervals.

UNIT IV: **(13 hours)**

Hypothesis Testing

Prior and posterior odds; Bayes factor for simple versus simple hypothesis; Lindley's procedure for test of significance.

PRACTICAL/LAB WORK: (30 HOURS)

List of Practical

Practical Work based on:

1. Plotting of Prior and posterior distributions for Binomial distribution case.
2. Plotting of Prior and posterior distributions for Poisson distribution case.
3. Bayes Estimation using Normal distribution and Squared error loss function.
4. Bayes Estimation using Binomial distribution and Absolute error loss function.
5. Construction of credible intervals and their comparison with corresponding classical confidence interval for Normal distribution case.
6. Construction of credible intervals and their comparison with corresponding classical confidence interval for Binomial distribution case.
7. Normal Approximation to Posterior Distribution.
8. Construction of HPD credible interval for Normal distribution case.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Barnett, V. (1982). Comparative Statistical Inference, J. Wiley, New York.
- Bansal, A.K. (2007). Bayesian Parametric Inference, Narosa Publishing House.
- Berger, J.O. (1985). Statistical Decision Theory and Bayesian analysis, Second Edition, Springer-Verlag, New York.

SUGGESTED READINGS:

- Box, G.E.P. and Tiao, G.C. (1973). Bayesian Inference in Statistical Analysis, Addison-Wesley.
- Lee, P. M. (1997). Bayesian Statistics: An Introduction, Arnold Press.
- O'Hagan, A. and Forster, J. (2004). Kendall's Advanced theory of Statistics, Volume 2B, Bayesian Inference, Oxford University Press, New York.
- Robert, C.P. (2001). The Bayesian Choice: A Decision Theoretic Foundations to Computational Implementation, Second Edition, Springer-Verlag, New York.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERAL ELECTIVE COURSE – 7C: ELEMENTS OF STOCHASTIC PROCESS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Stochastic Process	4	3	0	1	Class XII pass with Mathematics.	Basic knowledge of Statistics, Probability theory, and discrete Probability distributions

Learning Objectives:

The learning objectives include:

- Introduce the concept of probability generating function
- To understand transitions through Markov chains
- To identify real-life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of stochastic processes.
- The basic concepts of probability generating functions and it's applications.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Basic applications of Markov chains.
- Poisson processes and its properties.

SYLLABUS OF GE-7c

Theory

UNIT I **(15 hours)**

Generating functions, probability generating functions and their applications in discrete distributions. Stochastic Process: Parametric space and State space with examples. Covariance Stationary processes.

UNIT II **(15 hours)**

Markov Chains: Definition of Markov Chain, States of Markov chain, transition probability matrix, order of Markov chain, higher transition probabilities of Markov chain.

Classification of States as Transient, Persistent, Null, Non-null, and Ergodic. Reducible and irreducible Markov chains, Stability of Markov system(numerical only).

UNIT III **(15 hours)**

Poisson Process: postulates of Poisson process, properties and applications of Poisson process.

PRACTICAL/LAB WORK – (30 hours)

List of Practicals:

1. Generating probability distributions- Binomial, Poisson and geometric and obtaining their pgfs.
2. Generating sequence of numbers using the given generating function.
3. Computing probability generating function using the given sequence of probabilities and obtaining the mean & variance of the r.v. from the pgf.
4. Extracting probability distributions from the probability generating functions.
5. Examining covariance stationarity of a stochastic process.
6. Constructing the transition probability matrix from the given problem and calculating various probabilities.
7. Computing higher order probabilities from a given t.p.m.
8. Classifying the states of a Markov chain
9. Determining irreducibility of a Markov chain
10. Obtaining stable solution of a Markov chain.
11. Verifying additive property of a Poisson process.
12. Decomposition of a Poisson process.
13. Obtaining the autocorrelation function of a Poisson process.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Medhi, J. (2009). Stochastic Processes, New Age International Publishers.
- Gupta and Kapoor (2020). Fundamentals of Statistics, 12th edition, Sultan Chand and sons.

SUGGESTIVE READINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- Bhat,B.R. (2000). Stochastic Models: Analysis and Applications, New Age International Publishers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B. Sc. (H) Statistics Semester-VIII

Category I

DISCIPLINE SPECIFIC CORE COURSE-20: BAYESIAN INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title and code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorial	practicals		
Bayesian Inference	**4**	**3**	**0**	**1**	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives:

The learning objectives of this course is

- To introduce students to the Bayesian approach to statistics.
- To make students understand the basic difference between the commonly-taught Frequentist approach and the Bayesian Paradigm.
- To demonstrate the benefits of using a Bayesian approach and obtaining results that are more interpretable.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Bayes theorem for random variables
- Prior and posterior distributions
- Conjugate prior
- Non-informative priors
- Bayesian point estimation
- Bayesian Credible intervals
- Bayes factor

SYLLABUS OF DSC-20

Theory

UNIT I **(5 Hours)**

Bayes Theorem for Random Variables

Concept of inverse probability; Bayes theorem for random variables; Concept of likelihood function, prior distribution and posterior distribution.

UNIT II **(12 Hours)**

Conjugate Prior and Non-Informative Priors

Thumb rule for constructing a conjugate prior; Conjugate families for samples from various standard distributions; Uniform prior; Jeffreys' non-informative priors; Normal approximations to posterior distribution.

UNIT III **(15 Hours)**

Bayes Estimation and Credible Interval

Elements of Bayes Decision Theory; Loss Functions such as Squared error loss function, Bilinear loss function; Bayes risk; Normal and Extensive form of analysis; Duality between loss and prior; Generalised maximum likelihood estimate; Bayesian credible intervals; Difference between Bayesian credible intervals and classical confidence intervals; Application in linear regression model.

UNIT IV **(13 hours)**

Hypothesis Testing

Prior and posterior odds; Bayes factor for simple versus simple hypothesis; Bayes factor for composite versus composite hypothesis; Lindley's procedure for test of significance.

PRACTICAL / LAB WORK – 30 Hours

List of Practicals:

1. Plotting of Prior and posterior distributions for Binomial distribution case.
2. Plotting of Prior and posterior distributions for Poisson distribution case.
3. Bayes Estimation using Normal distribution and Squared error loss function.
4. Bayes Estimation using Binomial distribution and Absolute error loss function.
5. Construction of credible intervals and their comparison with corresponding classical confidence interval for Normal distribution case.
6. Construction of credible intervals and their comparison with corresponding classical confidence interval for Binomial distribution case.
7. Normal Approximation to Posterior Distribution.
8. Construction of HPD credible interval for Normal case.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Bansal, A.K. (2007). Bayesian Parametric Inference, Narosa Publishing House.
- Barnett, V. (1982). Comparative Statistical Inference, J. Wiley, New York.
- Berger, J.O. (1985). Statistical Decision Theory and Bayesian analysis, Second Edition, Springer-Verlag, New York.

SUGGESTED READINGS:

- Box, G.E.P. and Tiao, G.C. (1973). Bayesian Inference in Statistical Analysis, Addison-Wesley.
- Lee, P. M. (1997). Bayesian Statistics: An Introduction, Arnold Press.
- O'Hagan, A. and Forster, J. (2004). Kendall's Advanced theory of Statistics, Volume 2B, Bayesian Inference, Oxford University Press, New York.
- Robert, C.P. (2001). The Bayesian Choice: A Decision Theoretic Foundations to Computational Implementation, Second Edition, Springer-Verlag, New York.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective for B. Sc. (H) Statistics Semester-VIII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6A: NON-PARAMETRIC TESTING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nonparametric Testing	4	3	0	1	Class XII pass with Mathematics	Knowledge of Hypothesis testing

Learning Objectives

The learning objectives include:

- Usefulness of Nonparametric/distribution free tests their strength and weaknesses
- Quantile and Empirical distributions and their utility
- Test for randomness, location and scales under nonparametric setup
- Test association of bivariate samples

Learning Outcomes

After completing this course, students should have developed a clear understanding of:

- Make distinction between Parametric and Nonparametric test and measurement scales.
- Appreciate the role of quantile and empirical distribution function and associated tests.
- Identify suitable nonparametric test for both location and scale and able to apply one/two tests including Kolmogorov- Smirnov one sample and two sample tests, sign test, Wilcoxon signed rank test, run test. Median test, Kruskal-Wallis one-way analysis of variance by ranks, Friedman two way analysis of variance by ranks.

- Test association of bivariate samples using Kendall tau and Spearman's rank correlation.

SYLLABUS OF DSE-6A

Theory

UNIT I **(15 hours)**

Introduction

Nonparametric Tests: Non-parametric tests-their advantages and disadvantages, comparison with parametric tests. Measurement scale-nominal, ordinal, interval and ratio. The quantile function, the empirical distribution function, Glivenko Cantelli Theorem (without proof), Kolmogorov Goodness of fit test, confidence interval for a population quantile, hypothesis testing for a population quantile.

UNIT II **(15 hours)**

One sample and two sample tests

One-Sample, two-sample problem and Paired-Sample Procedures: the sign test and confidence interval for the median, rank-order statistics, treatment of ties in rank tests, Wilcoxon signed-rank test, confidence interval, Wald-Wolfowitz runs test, Kolmogorov-Smirnov one and two-sample test, median test and the Mann-Whitney U test.

UNIT III **(15 hours)**

K sample tests

Linear Rank Tests for the Location and Scale Problem: Definition of linear rank statistics, Wilcoxon rank-sum test; Tests of the Equality of k Independent Samples: The Kruskal-Wallis one-way ANOVA test and multiple comparisons.; Measures of Association for Bivariate Samples: definition of measures of association in a bivariate population, Kendall's Tau coefficient, Spearman's coefficient of rank correlation.

PRACTICAL/LAB WORK (30 hours):

List of Practical:

1. Obtaining quantile and Empirical Distribution
2. Test for randomness
3. Sign test
4. Wilcoxon Signed rank test
5. Wald-Wolfowitz runs test,
6. Kolmogorov-Smirnov one and two-sample test,
7. median test and the Mann-Whitney U test.
8. Wilcoxon rank-sum test
9. The Kruskal-Wallis one-way ANOVA test
10. Test based on Kendall's Tau coefficient.
11. Spearman's coefficient of rank correlation

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gibbons, J. D., and Chakraborti, S. (2020): Nonparametric statistical inference. CRC press.
- Siegel, S. (1956). Nonparametric statistics for the behavioral sciences. McGraw-Hill.

SUGGESTIVE READINGS:

- Kloke, J., and McKean, J. W. (2014) : Nonparametric statistical methods using R. CRC Press.
- Hollander, M., Wolfe, D. A., and Chicken, E. (2013): Nonparametric statistical methods (Vol. 751). John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6B: RELIABILITY THEORY AND LIFE TESTING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory And Life Testing	4	3	0	1	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives

The learning objectives include:

- To understand the reliability and their application area.
- To develop the thinking of students so that they can use the concepts of reliability in real life scenario.
- To determine if the performance of components, equipment, and systems, either under closely controlled and known stress conditions in a testing laboratory or under field use conditions.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of Reliability and life testing.
- Various estimation procedures of reliability function(s).

- Comparison of various estimates of reliability through simulation study using different software.
- Real data fitting in reliability modelling

SYLLABUS OF DSE-6B

THEORY

UNIT I **(12 hours)**

Reliability and reliability measures

Definition of components and systems, coherent systems, Reliability, Maintainability and Availability; Lifetime distributions, failure rates, MTTF, Bathtub failure rate, reliability of coherent systems in terms of paths and cuts, modular decomposition, reliability importance of components; Parametric families of some common lifetime distributions and their properties (Exponential, Weibull and Gamma).

UNIT II **(10 hours)**

Reliability estimation

Various methods of reliability estimation (Classical and Bayesian);Exponential, Weibull and Gamma lifetime distributions, Reliability estimation under complete, truncated and censored samples, estimates based on components of ordered statistics.

UNIT III **(10 hours)**

Stress-Strength and multicomponent reliability

Stress-Strength reliability: concepts and its estimation for exponential, Weibull and gammadistributions, k-out-of-n (exponential and gamma). Mixture distribution, convolutions and competing risks: introduction, mixture of exponentials, mixture of Weibull, competing risk.Bayesian Approximation and Reliability: Lindley's expansion, reliability estimation (Normal and Weibull)

UNIT IV **(13 hours)**

Reliability systems and life testing

Reliability of series/parallel systems: introduction, series systems with identical components. Reliability bounds (classical and Bayesian approaches), parallel systems.Different types of redundancy and use of redundancy in reliability improvement. Problems of life testing.Notions of Ageing: IFR, IFRA, NBU, DMRL, NBUE and HNBUE classes, their duals and relationship between them.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate, MTBF for various systems.
3. Calculation of stress-strength reliability and its estimates.
4. Various reliability and hazard rate plots.
5. Validation of reliability estimates through simulation study.
6. Behavior of reliability estimates corresponding to sample size.
7. Behavior of hazard rates corresponding to different values of parameter(s).
8. Effect of different sample sizes on reliability estimates.
9. Comparison of various methods of estimation of reliability through simulation study.

10. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Balagurusamy (2017): Reliability Engineering; Wiley
- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless, J.F. (2003): Statistical Models and Methods of Life Time Data; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.
- Nelson, W (2003): Applied Life Data Analysis; John Wiley.
- Rand M and Hoyland A (2004): System reliability theory, Models, Statistical methods and itsapplications;Wiley.
- Zacks, S(1992): Introdcution to Reliability Analysis, Springer Verlag

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE-6C: GENERALIZED LINEAR MODELS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	tutorials	practical		
Generalized Linear Models	**4**	**3**	**0**	**1**	Class XII pass with Mathematics	Knowledge of general linear models

Learning Objectives:

learning objectives include:

- Provide the ability to learn and use linear and non-linear models for normal data
- Developing ability to learn generalized linear models for normal and non-normal responses.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Use linear and Non-linear models, apply data transformations, and appreciate the need and uses of generalized linear models.
- Use logistic and Poisson regression models.
- Understand deviance, analysis of deviance, Lack-of-Fit tests in Logistic and Poisson regression, and the concept of overdispersion.
- Use Log linear models for contingency tables, and likelihood ratio tests for various hypotheses including independence, marginal and conditional independence, and partial association.
- Understand graphical and non-graphical models.
- Use the concepts of Generalized Linear Models in real life problems.

SYLLABUS OF DSE-6C

UNIT I **(11 Hours)**

Nonlinear Regression Models

Review of linear regression models, Nonlinear regression models, Origins of Nonlinear Models, Transforming to a Linear Model, Estimation of parameters and Statistical Inferences in nonlinear regression.

UNIT II **(12 Hours)**

Logistic regression models

Logistic regression models, Estimation of parameters, Statistical Inferences on model parameters, Confidence Intervals, Lack-of-Fit tests, and Diagnostic checking in Logistic regression.

UNIT III **(12 Hours)**

Poisson Regression Models

Poisson regression models, Estimation of parameters in Poisson regression, Applications in Poisson regressions. Overdispersion in Logistic and Poisson regression models. Link function.

UNIT IV **(10 Hours)**

Log-Linear Models

Log-linear models for contingency tables: interpretation of parameters, Estimation of parameters, likelihood ratio tests for various hypotheses, Graphical and decomposable models.

PRACTICAL/LABWORK -30 Hours

List of Practicals

1. Fitting of non-linear regression model.
2. Fitting of logistic regression model.
3. Tests of hypotheses about parameters.
4. Analysis of deviance.
5. Lack-of-Fit tests in Logistic regression.

6. Fitting of Poisson regression model.
7. Log-linear models for contingency tables.
8. Tests for independence,
9. Tests for marginal and conditional independence,
10. Tests for partial association.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Dobson, A.J. and Barnett, A.G. (2018): Introduction to Generalized Linear Models, 4th ed., Chapman and Hall/CRC. London.
- Myers, R.H., Montgomery, D.C., Vining, G.G. and Robinson, T.J. (2010): Generalized Linear Models with Applications in Engineering and the Sciences, 2nd ed., John Wiley & Sons.

SUGGESTED READINGS:

- McCullagh, P. and Nelder, J.A. (1989): Generalized Linear Models, 2nd ed., Chapman and Hall.
- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6D: ADVANCED STOCHASTIC PROCESSES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Stochastic Processes	4	3	0	1	Class XII pass with Mathematics.	Advanced knowledge of Probability theory and Probability distributions

Learning Objectives:

The learning objectives include:

- To define, design and build stochastic models
- To model and analyze transitions through Markov chains
- To identify the real life applications of stochastic processes.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Tools needed to analyze stochastic processes.
- Markov chain applications.
- Concept of population growth and extinction of population with Branching Process.
- Recurrence of events based on renewal theory.
- Poisson processes and their applications in Birth and Death models.
- Queuing models and their applications

SYLLABUS OF DSE-6d

Theory

UNIT I **(13 hours)**

Determination Of Higher Transition Probabilities, Aperiodic Chain: Limiting Behaviour, Graph Theoretic Approach, Finite Reducible Chains with a Single non- trivial Closed Class

UNIT II **(15 hours)**

Concept of Characteristic functions, Laplace, and Inverse Laplace Transformations.
Branching Process , properties of generating functions of branching processes, probability of ultimate extinction, and its application.
Renewal Processes in Discrete Time, Relation Between F(s) and P(s) and Renewal Interval.

UNIT III **(12 hours)**

Pure Birth Process, Pure Death Process, Birth And Death Process, Linear Growth Models, Queueing Processes, Steady State Distribution, Little's Formula, Poisson Queuing Models M/M/1: GD/∞/∞ and its characteristics, waiting time distribution under this model, M/M/1: GD/N/∞ and characteristics, Average system length, Average queue length, M/M/C: GD/∞/∞ and its characteristics average queue length, average system length, average waiting time, and problems based on all three models.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Simulation of Markov chains.
2. Calculation of higher transition probability matrices.
3. To check whether the given chain is irreducible or not using the concept of stationarity
4. Classification of states.
5. Extinction of population under GW branching Process.
6. Problems based on Renewal theory.
7. Simulation and applications of Poisson processes.
8. Generate the Yule-Furry process and verify that the process follows a geometric distribution.
9. Mean size of population and probability of extinction under linear growth process.
10. Computation of expected customers in the system and expected queue length under (M/M/1);(GD/∞/∞) queuing system.
11. Computation of the Average length of a non-empty queue and the fluctuation (variance) of the number of customers in the system under (M/M/1);(GD/∞/∞) queuing system.
12. Computation of expected number of customers in the system and expected queue length under (M/M/1);(GD/N/∞) queuing system.
13. Computation of expected number of customers in the system and expected queue length under (M/M/C);(GD/N/∞) queuing system .

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol I, 3rd Ed., Wiley International.
- Medhi, J. (2009). Stochastic Processes, New Age International Publishers.
- Sheldon M. Ross (2007) : Introduction to Probability Models, 9th edition, Academic Press publications
- Karlin & Taylor (1975) : A first course in stochastic processes, 2nd edition, Academic Press publications

SUGGESTIVE READINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Stochastic Processes.
- J. G. Kemeny, J. L. Snell and A. W. Knapp: Finite Markov Chains.
- Geoffrey R, Grimmett & David R. Stirzaker : Probability and Random Processes

Bhat,B.R. (2000). Stochastic Models: Analysis and Applications, New Age International Publishers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.A(Prog) with Statistics as Non-Major/Major Semester-VIII

Category II

DISCIPLINE SPECIFIC CORE COURSE –8: FUNDAMENTALS OF ECONOMETRICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Fundamentals of Econometrics	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- Interpretation and critical evaluation of the outcomes of empirical analysis.
- To judge the validity of the economic theories
- To carry out evaluation of economic theories in numerical terms
- To extract useful information about important economic policy issues from the available data.
- The course is designed to provide the students with the basic quantitative techniques needed to undertake applied research projects.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of econometrics.
- Specification of the model.
- Simple Linear Regression.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.

SYLLABUS OF DSC-8

Theory

UNIT I **(15 hours)**

Introduction

Nature and Scope of Econometrics: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, interpretation of regression, nature and sources of data for econometric analysis, different measurement scales of variables

UNIT II (15 hours)

Regression Models

Simple and Multiple Linear Regression Model: Estimation of model by method of ordinary least squares(OLS), properties of estimators, goodness of fit, tests of hypotheses, confidence intervals, coefficient of determination, Gauss-Markov theorem and forecasting.

UNIT III (5 hours)

Autocorrelation

Autocorrelation: Concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

UNIT IV (10 hours)

Multicollinearity and Heteroscedasticity

Violations of Classical Assumptions: Multicollinearity- Concept, Consequences, Detection and Remedies. Heteroscedasticity and serial correlation– Concept and Consequences.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Problems based on estimation of simple linear model.
2. Testing of parameters of simple linear model.
3. Multiple Regression.
4. Problems concerning specification errors.
5. Problems related to consequences of Multicollinearity.
6. Diagnostics of Multicollinearity.
7. Problems related to consequences Heteroscedasticity.
8. Diagnostics of Heteroscedasticity.
9. Estimation of problems of General linear model under Heteroscedastic distance terms.
10. Problems related to selection of best regression model.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gujarati, D. and Guneshker, S. (2007). Basic Econometrics, 4th Ed., McGraw Hill Companies.
- Johnston, J. (1972). Econometric Methods, 2nd Ed., McGraw Hill International.

SUGGESTIVE READINGS:

- Koutsoyiannis, A. (2004). Theory of Econometrics, 2 Ed., Palgrave Macmillan Limited.

- Maddala, G.S. and Lahiri, K. (2009). Introduction to Econometrics, 4 Ed., John Wiley & Sons.
- Greene, W. H. (2002) Econometric Analysis.5th Edition, Prentice Hall.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective for B.A. (Prog) with Statistics as Non-Major/Major Semester-VIII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6A: INTRODUCTION TO NON-PARAMETRIC METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Non-Parametric Methods	4	3	0	1	Class XII pass with Mathematics	Knowledge of elementary Statistical Inference

Learning Objectives

learning objectives include:

- To understand the basic principles and concepts of non-parametric statistics.
- To learn the different types of non-parametric statistical tests and their applications.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Develop an understanding of the differences between parametric and non-parametric statistical tests and their advantages and disadvantages.
- Be able to apply and interpret the results of various non-parametric tests for hypothesis testing, goodness-of-fit testing, testing for randomness, and measuring the association between variables.

SYLLABUS OF DSE-6A

Theory

UNIT I **(11 hours)**

Introduction

Introduction: Definition of non-parametric statistics, Various scales of measurements – the Nominal or categorical scale, the Ordinal or ranking scale, the interval scale and the ratio scale. The differences between parametric and non-parametric statistical tests. Advantages and disadvantages of non-parametric statistical tests.

UNIT II **(15 hours)**

One Sample Tests

One-Sample Tests: Chi-Square Goodness of Fit Test for testing whether a sample comes from a specific distribution; Kolmogorov-Smirnov Test for goodness of fit, One Sample Runs Test for Randomness to test for independence of the order of observations in the sequence. Testing the difference between the median of a sample and a hypothesized value: Sign Test, Wilcoxon Signed-Rank Test.

UNIT III **(19 hours)**

K Sample Tests

Two-Sample Tests: Whether two samples come from the same continuous distribution-Wald-Wolfowitz Runs test, Kolmogorov-Smirnov test. Test for the difference between the medians of two independent samples - Median Test, Mann-Whitney U Test. Comparison of medians of *k* independent samples - Kruskal-Wallis one-way analysis of variance by ranks. Measure of association between two variables - Spearman Rank-Order correlation coefficient and significance.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practicals based on

1. Chi-Square Goodness of Fit Test
2. Kolmogorov-Smirnov One Sample Test
3. One Sample Runs Test for Randomness
4. Sign Test
5. Wilcoxon Signed-Rank Test.
6. Wald-Wolfowitz Runs Test
7. Kolmogorov-Smirnov Two-Sample Test
8. Median Test
9. Wilcoxon-Mann-Whitney U Test
10. Kruskal-Wallis one-way analysis of variance by ranks
11. Spearman Rank-Order correlation coefficient

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Gun, A. M., Gupta, M. K., & Dasgupta, B. (2013). An outline of statistical theory. World Press Pvt Limited.
- Siegel, Sidney, and N. John Jr. "Castellan. 1988. Nonparametric Statistics for the Behavioral Sciences." New York (6).
- Gibbons, J. D., & Chakraborti, S. (2014). Nonparametric statistical inference. CRC press.

SUGGESTIVE READINGS:

- Sprent, P., & Smeeton, N. C. (2016). *Applied nonparametric statistical methods*. CRC press.
- Sheskin, D. J. (2011). Handbook of parametric and nonparametric statistical procedures, CRC Press. Boca Raton, FL.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6B: RELIABILITY THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory	4	3	0	1	Class XII pass with Mathematics	knowledge of probability distributions

Learning Objectives

The learning objectives include:

- To describe the theoretical aspects of reliability along with their application area.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of Reliability, Maintainability and Availability.
- Various estimation procedures of reliability function(s).
- Calculate the Reliability of series and parallel systems.

SYLLABUS OF DSE-6B

Theory

UNIT I **(10 hours)**

Reliability measures

Definition of Components, systems and coherent systems. Reliability functions, hazard rate function, reverse hazard rate function, residual lifetime, inactivity time, mean residual lifetime function, mean inactivity time, reliability bounds, cut and path sets.

UNIT II (08 hours)

Common lifetime distributions

Common lifetime distributions and their properties (Exponential, Weibull and Gamma), scale model, proportional hazard rate model, proportional reverse hazard rate model, MTTF, Bathtub failure rate, reliability importance of components.

UNIT III (12 hours)

Estimation of reliability functions

Various methods of reliability estimation (Classical); of some common lifetime distributions, Reliability estimation under complete and various censored samples. Stress-Strength reliability: concepts and its estimation for exponential and Weibull, k-out-of-n (exponential) and its application.

UNIT IV (15 hours)

Reliability systems and ageing

Reliability of series/parallel systems: introduction, series systems with identical components. Different types of redundancy. Notions of Ageing: Different ageing classes, ageing properties of common lifetime distributions, closure properties of different ageing classes under formation of coherent structures.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practical based on

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate for various models.
3. Calculation of stress-strength reliability.
4. Various reliability and hazard rate plots.
5. Behavior of reliability estimates corresponding to sample size.
6. Practicals on ageing.
7. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless, J.F. (2003): Statistical Models and Methods of Life Time Data; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6C: MULTIVARIATE DATA ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Data Analysis	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- To study the concept of Bivariate Normal Distribution along with their properties.
- To study the concept of Multivariate Normal Distribution along with their properties and analysis of multivariate data.
- Concepts of regression plane, multiple and partial correlation coefficients.
- Applications of discriminant analysis, principal component analysis and factor analysis.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- The understanding of regression plane, multiple and partial correlation coefficients.
- Analysing multivariate data using data reduction techniques like principal component analysis, factor analysis.
- Classification method namely discriminant analysis.

SYLLABUS OF DSE-6C

Theory

UNIT 1 **(16 hours)**

Bivariate Normal Distribution:

Probability density function of Bivariate Normal Distribution. Moment generating function, marginal, conditional pdf of BVN and properties of BVN. Introduction of random vector, probability mass/ density functions, distribution function, mean vector and dispersion matrix. Marginal and conditional distributions of random vector.

UNIT 2 **(16 hours)**

Multivariate Normal distribution:

Probability density function and properties of Multivariate Normal distribution. Moment generating function, marginal and conditional pdf of MVN. Sampling distribution for mean vector and variance-covariance matrix. Regression plane, multiple and partial correlation coefficient and their properties.

UNIT 3 **(13 hours)**

Data Analysis

Data Reduction Techniques: Principal component analysis and its applications, Factor analysis and its applications. Discriminant analysis and its applications.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practicals based on

1. Bivariate Normal Distribution and its properties.
2. Mean vector and dispersion matrix of Multivariate Normal Distribution.
3. Marginal distributions of Multivariate Normal Distribution.
4. Conditional distributions of Multivariate Normal Distribution.
5. Regression space.
6. Partial Correlation Coefficient.
7. Multiple Correlation Coefficient.
8. Principal Component Analysis.
9. Discriminant analysis.
10. Factor Analysis.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, 3rd Ed., John Wiley & Sons.
- Johnson, R.A. and Wichern, D.W. (2007). *Applied Multivariate Analysis*, 6th Ed., Prentice Hall.
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005). *An Outline of Statistical Theory*, Volume II, World Press.
- Brian S. Everett and Graham Dunn. (2001). *Applied multivariate data analysis*, second edition, Oxford University Press.

SUGGESTED READINGS

- S.C. Gupta and V.K. Kapoor (2020). *Fundamentals of Mathematical Statistics*, 12th Ed., Sultan Chand and Sons.
- Kshirsagar, A.M. (1972). *Multivariate Analysis*, 1st Ed., Marcel Dekker.
- Muirhead, R.J. (1982). *Aspects of Multivariate Statistical Theory*, John Wiley.
- Arora, S. and Bansi, L. (1968). *New Mathematical Statistics*, 1st Ed., Vanita Printers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6D: STATISTICAL SIMULATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Simulation	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives

The learning objectives include:

- Concept of simulation and simulation modelling.
- Generation of Pseudo random number generators as well as from standard statisticaldistributions. Monte-Carlo simulation technique.
- Application of simulation techniques.

Learning Outcomes

After completing this course, students will possess skills concerning:

- How simulation may be used to understand the behavior of real world systems by utilizing mathematical models with an emphasis on simulation.
- How to generate random numbers by the different methods.
- Hands-on experience in using simulation software packages/structured programming languages.

SYLLABUS OF DSE- 6D

Theory

Unit I **(12 Hours)**

Introduction to simulation:

Introduction, Definitions of simulation, Need for simulation, general principles, types of simulation, Simulation models, Phases in simulation models, Event type simulation, Monte Carlo simulation technique.

Unit II **(18 Hours)**

Random numbers generation:

Methods for the generation of Random numbers, Pseudo random number generators, Mid square method for the generation of random number and its limitations, the inverse transform method; Generating the Discrete and Continuous random variables.

Unit III **(15 Hours)**

Applications of simulation:

Applications of simulation in different fields of study, simulation of Inventory problems and simulation of Queueing problems. Advantages and disadvantages of simulation, Simulation languages, Scope of simulation techniques.

Practical/Lab Work–(30 hours)

List of Practical:

1. Pseudo random number generators;
2. Generation of U(0,1).
3. Generation using the inverse transform method applied to:
4. Discrete distribution and
5. Continuous distribution.
6. Monte Carlo simulation method and applications.
7. Problems based on Queueing systems.
8. Problems based on Inventory Controls, etc.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Sheldon M. Ross (2022) *Simulation, Sixth Edition,* Elsevier Academic press publication.
- Taha, H. A. (2010). *Operations Research. An Introduction*, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). *Operations Research, 15th Ed,* Sultan Chand & Sons.

SUGGESTED READINGS:

- Voss, J. (2013). *An introduction to statistical computing: A simulation-based approach,* 1st Ed., Wiley series in computational statistics.
- Sharma, J. K. (2017). *Operations Research: Theory and applications, 6th Edition,* Trinity Press.
- Payer T.A. (1982). *Introduction to simulation,* McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (Prog) Mathematical Sciences with Statistics Semester-VIII

Category II

DISCIPLINE SPECIFIC CORE COURSE –8: FUNDAMENTALS OF ECONOMETRICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Fundamentals of Econometrics	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- Interpretation and critical evaluation of the outcomes of empirical analysis.
- To judge the validity of the economic theories
- To carry out evaluation of economic theories in numerical terms
- To extract useful information about important economic policy issues from the available data.
- The course is designed to provide the students with the basic quantitative techniques needed to undertake applied research projects.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The fundamental concepts of econometrics.
- Specification of the model.
- Simple Linear Regression.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.

SYLLABUS OF DSC-8

Theory

UNIT I **(15 hours)**

Introduction

Nature and Scope of Econometrics: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, interpretation of regression, nature and sources of data for econometric analysis, different measurement scales of variables

UNIT II (15 hours)

Regression Models

Simple and Multiple Linear Regression Model: Estimation of model by method of ordinary least squares(OLS), properties of estimators, goodness of fit, tests of hypotheses, confidence intervals, coefficient of determination, Gauss-Markov theorem and forecasting.

UNIT III (5 hours)

Autocorrelation

Autocorrelation: Concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

UNIT IV (10 hours)

Multicollinearity and Heteroscedasticity

Violations of Classical Assumptions: Multicollinearity- Concept, Consequences, Detection and Remedies. Heteroscedasticity and serial correlation– Concept and Consequences.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Problems based on estimation of simple linear model.
2. Testing of parameters of simple linear model.
3. Multiple Regression.
4. Problems concerning specification errors.
5. Problems related to consequences of Multicollinearity.
6. Diagnostics of Multicollinearity.
7. Problems related to consequences Heteroscedasticity.
8. Diagnostics of Heteroscedasticity.
9. Estimation of problems of General linear model under Heteroscedastic distance terms.
10. Problems related to selection of best regression model.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gujarati, D. and Guneshker, S. (2007). Basic Econometrics, 4th Ed., McGraw Hill Companies.
- Johnston, J. (1972). Econometric Methods, 2nd Ed., McGraw Hill International.

SUGGESTIVE READINGS:

- Koutsoyiannis, A. (2004). Theory of Econometrics, 2 Ed., Palgrave Macmillan Limited.

- Maddala, G.S. and Lahiri, K. (2009). Introduction to Econometrics, 4 Ed., John Wiley & Sons.
- Greene, W. H. (2002) Econometric Analysis.5th Edition, Prentice Hall.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective for B.Sc. (Prog) Mathematical Sciences with Statistics Semester-VIII

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6A: INTRODUCTION TO NON-PARAMETRIC METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Non-Parametric Methods	4	3	0	1	Class XII pass with Mathematics	Knowledge of elementary Statistical Inference

Learning Objectives

learning objectives include:

- To understand the basic principles and concepts of non-parametric statistics.
- To learn the different types of non-parametric statistical tests and their applications.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Develop an understanding of the differences between parametric and non-parametric statistical tests and their advantages and disadvantages.
- Be able to apply and interpret the results of various non-parametric tests for hypothesis testing, goodness-of-fit testing, testing for randomness, and measuring the association between variables.

SYLLABUS OF DSE-6A

Theory

UNIT I **(11 hours)**

Introduction

Introduction: Definition of non-parametric statistics, Various scales of measurements – the Nominal or categorical scale, the Ordinal or ranking scale, the interval scale and the ratio scale. The differences between parametric and non-parametric statistical tests. Advantages and disadvantages of non-parametric statistical tests.

UNIT II **(15 hours)**

One Sample Tests

One-Sample Tests: Chi-Square Goodness of Fit Test for testing whether a sample comes from a specific distribution; Kolmogorov-Smirnov Test for goodness of fit, One Sample Runs Test for Randomness to test for independence of the order of observations in the sequence. Testing the difference between the median of a sample and a hypothesized value: Sign Test, Wilcoxon Signed-Rank Test.

UNIT III **(19 hours)**

K Sample Tests

Two-Sample Tests: Whether two samples come from the same continuous distribution-Wald-Wolfowitz Runs test, Kolmogorov-Smirnov test. Test for the difference between the medians of two independent samples - Median Test, Mann-Whitney U Test. Comparison of medians of *k* independent samples - Kruskal-Wallis one-way analysis of variance by ranks. Measure of association between two variables - Spearman Rank-Order correlation coefficient and significance.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practicals based on

1. Chi-Square Goodness of Fit Test
2. Kolmogorov-Smirnov One Sample Test
3. One Sample Runs Test for Randomness
4. Sign Test
5. Wilcoxon Signed-Rank Test.
6. Wald-Wolfowitz Runs Test
7. Kolmogorov-Smirnov Two-Sample Test
8. Median Test
9. Wilcoxon-Mann-Whitney U Test
10. Kruskal-Wallis one-way analysis of variance by ranks
11. Spearman Rank-Order correlation coefficient

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Gun, A. M., Gupta, M. K., & Dasgupta, B. (2013). An outline of statistical theory. World Press Pvt Limited.
- Siegel, Sidney, and N. John Jr. "Castellan. 1988. Nonparametric Statistics for the Behavioral Sciences." New York (6).
- Gibbons, J. D., & Chakraborti, S. (2014). Nonparametric statistical inference. CRC press.

SUGGESTIVE READINGS:

- Sprent, P., & Smeeton, N. C. (2016). *Applied nonparametric statistical methods*. CRC press.
- Sheskin, D. J. (2011). Handbook of parametric and nonparametric statistical procedures, CRC Press. Boca Raton, FL.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6B: RELIABILITY THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory	4	3	0	1	Class XII pass with Mathematics	knowledge of probability distributions

Learning Objectives

The learning objectives include:

- To describe the theoretical aspects of reliability along with their application area.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of Reliability, Maintainability and Availability.
- Various estimation procedures of reliability function(s).
- Calculate the Reliabilityg of series and parallel systems.

SYLLABUS OF DSE-6B

Theory

UNIT I **(10 hours)**

Reliability measures

Definition of Components, systems and coherent systems. Reliability functions, hazard rate function, reverse hazard rate function, residual lifetime, inactivity time, mean residual lifetime function, mean inactivity time, reliability bounds, cut and path sets.

UNIT II **(08 hours)**

Common lifetime distributions

Common lifetime distributions and their properties (Exponential, Weibull and Gamma), scale model, proportional hazard rate model, proportional reverse hazard rate model, MTTF, Bathtub failure rate, reliability importance of components.

UNIT III **(12 hours)**

Estimation of reliability functions

Various methods of reliability estimation (Classical); of some common lifetime distributions, Reliability estimation under complete and various censored samples. Stress-Strength reliability: concepts and its estimation for exponential and Weibull, k-out-of-n (exponential) and its application.

UNIT IV **(15 hours)**

Reliability systems and ageing

Reliability of series/parallel systems: introduction, series systems with identical components. Different types of redundancy. Notions of Ageing: Different ageing classes, ageing properties of common lifetime distributions, closure properties of different ageing classes under formation of coherent structures.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:

Practical based on
1. Calculation of reliability function and its estimates
2. Calculation of hazard rate for various models.
3. Calculation of stress-strength reliability.
4. Various reliability and hazard rate plots.
5. Behavior of reliability estimates corresponding to sample size.
6. Practicals on ageing.
7. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.

- Lawless, J.F. (2003): Statistical Models and Methods of Life Time Data; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6C: MULTIVARIATE DATA ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Data Analysis	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions

Learning Objectives

The learning objectives include:

- To study the concept of Bivariate Normal Distribution along with their properties.
- To study the concept of Multivariate Normal Distribution along with their properties and analysis of multivariate data.
- Concepts of regression plane, multiple and partial correlation coefficients.
- Applications of discriminant analysis, principal component analysis and factor analysis.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- The basic concepts associated with Multivariate Normal Distributions and their properties with special emphasis on Bivariate Normal Distribution.
- The understanding of regression plane, multiple and partial correlation coefficients.
- Analysing multivariate data using data reduction techniques like principal component analysis, factor analysis.
- Classification method namely discriminant analysis.

SYLLABUS OF DSE-6C

Theory

UNIT 1 **(16 hours)**

Bivariate Normal Distribution:

Probability density function of Bivariate Normal Distribution. Moment generating function, marginal, conditional pdf of BVN and properties of BVN. Introduction of random vector,

probability mass/ density functions, distribution function, mean vector and dispersion matrix. Marginal and conditional distributions of random vector.

UNIT 2 **(16 hours)**

Multivariate Normal distribution:

Probability density function and properties of Multivariate Normal distribution. Moment generating function, marginal and conditional pdf of MVN. Sampling distribution for mean vector and variance-covariance matrix. Regression plane, multiple and partial correlation coefficient and their properties.

UNIT 3 **(13 hours)**

Data Analysis

Data Reduction Techniques: Principal component analysis and its applications, Factor analysis and its applications. Discriminant analysis and its applications.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practicals based on

1. Bivariate Normal Distribution and its properties.
2. Mean vector and dispersion matrix of Multivariate Normal Distribution.
3. Marginal distributions of Multivariate Normal Distribution.
4. Conditional distributions of Multivariate Normal Distribution.
5. Regression space.
6. Partial Correlation Coefficient.
7. Multiple Correlation Coefficient.
8. Principal Component Analysis.
9. Discriminant analysis.
10. Factor Analysis.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Anderson, T.W. (2003). *An Introduction to Multivariate Statistical Analysis*, 3rd Ed., John Wiley & Sons.
- Johnson, R.A. and Wichern, D.W. (2007). *Applied Multivariate Analysis*, 6th Ed., Prentice Hall.
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005). *An Outline of Statistical Theory,* Volume II, World Press.
- Brian S. Everett and Graham Dunn. (2001). *Applied multivariate data analysis*, second edition, Oxford University Press.

SUGGESTED READINGS

- S.C. Gupta and V.K. Kapoor (2020). *Fundamentals of Mathematical Statistics*, 12th Ed., Sultan Chand and Sons.
- Kshirsagar, A.M. (1972). *Multivariate Analysis*, 1st Ed., Marcel Dekker.
- Muirhead, R.J. (1982). *Aspects of Multivariate Statistical Theory*, John Wiley.

- Arora, S. and Bansi, L. (1968). *New Mathematical Statistics*, 1st Ed., Vanita Printers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 6D: STATISTICAL SIMULATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Simulation	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives

The learning objectives include:

- Concept of simulation and simulation modelling.
- Generation of Pseudo random number generators as well as from standard statisticaldistributions. Monte-Carlo simulation technique.
- Application of simulation techniques.

Learning Outcomes

After completing this course, students will possess skills concerning:

- How simulation may be used to understand the behavior of real world systems by utilizing mathematical models with an emphasis on simulation.
- How to generate random numbers by the different methods.
- Hands-on experience in using simulation software packages/structured programming languages.

SYLLABUS OF DSE- 6D

Theory

Unit I **(12 Hours)**

Introduction to simulation:

Introduction, Definitions of simulation, Need for simulation, general principles, types of simulation, Simulation models, Phases in simulation models, Event type simulation, Monte Carlo simulation technique.

Unit II **(18 Hours)**

Random numbers generation:
Methods for the generation of Random numbers, Pseudo random number generators, Mid square method for the generation of random number and its limitations, the inverse transform method; Generating the Discrete and Continuous random variables.

Unit III **(15 Hours)**

Applications of simulation:
Applications of simulation in different fields of study, simulation of Inventory problems and simulation of Queueing problems. Advantages and disadvantages of simulation, Simulation languages, Scope of simulation techniques.

Practical/Lab Work–(30 hours)

List of Practical:

1. Pseudo random number generators;
2. Generation of U(0,1).
3. Generation using the inverse transform method applied to:
4. Discrete distribution and
5. Continuous distribution.
6. Monte Carlo simulation method and applications.
7. Problems based on Queueing systems.
8. Problems based on Inventory Controls, etc.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Sheldon M. Ross (2022) *Simulation, Sixth Edition,* Elsevier Academic press publication.
- Taha, H. A. (2010). *Operations Research. An Introduction*, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). *Operations Research, 15th Ed,* Sultan Chand & Sons.

SUGGESTED READINGS:

- Voss, J. (2013). *An introduction to statistical computing: A simulation-based approach,* 1st Ed., Wiley series in computational statistics.
- Sharma, J. K. (2017). *Operations Research: Theory and applications, 6th Edition,* Trinity Press.
- Payer T.A. (1982). *Introduction to simulation,* McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY DEPARTMENT OF STATISTICS (SEMESTER- VIII) CATEGORY-VI

GENERIC ELECTIVE COURSE – 8A: ORDER STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Order Statistics	4	3	0	1	Class XII pass with Mathematics	knowledge of statistical distributions and stochastic processes

Learning Objectives

The learning objective of this course is:

- To make the students aware of the properties and applications of order statistics.

Learning Outcomes:

After completion of this course, students should have developed a clear understanding of:

- Find joint, marginal, and conditional distributions of order statistics in the continuous and discrete cases.
- Find the distribution of sample range and other systematic statistics in case of sampling from an arbitrary continuous population and, in particular, from some specific continuous distributions such as uniform and exponential.
- Understand the Markov Chain property of order statistics in the continuous case.
- Understand the distribution-free bounds for moments of order statistics and of the range.
- Derive the recurrence relations and identities for moments of order statistics drawn from an arbitrary population (discrete or continuous), as well as from some specific distributions.
- Learn how to obtain distribution-free confidence intervals for population quantile and distribution-free tolerance intervals for population distributions based on order statistics

SYLLABUS OF GE-8a

Theory

UNIT I **(15 hours)**

Introduction

Introduction to order statistics. Basic distribution theory. Joint and marginal distributions of order statistics in the continuous case. Distribution of the range, median and other systematic statistics. Examples based on some specific continuous distributions.

UNIT II **(10 hours)**

Conditional distribution of order statistics

Conditional distributions. Order statistics as a Markov Chain. Order statistics for a discrete parent. Examples based on some specific discrete distributions.

UNIT III **(10 hours)**

Moments of order statistics

Moments of order statistics. Need of Recurrence relations and identities for moments of order statistics. Recurrence relations and identities for single and product moments of order statistics from an arbitrary distribution. Recurrence relations for single and product moments of order statistics from some specific distributions.

UNIT IV **(10 hours)**

Distribution- free intervals of order statistics

Distribution-free confidence intervals for population quantiles and distribution-free tolerance intervals. Distribution-free bounds for moments of order statistics and of the range.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Problem solving using joint, marginal and conditional distributions of order statistics for some specific continuous distributions.
2. Distribution-free confidence intervals for population quantiles for various distributions.
3. Calculating Means, variances, and covariances by using exact expressions for the moment of order statistics for some specific continuous distribution.
4. Problems based on Markov Chain property of order statistics in the continuous case.
5. Distribution of sample range and other systematic statistics in sampling from differentdistributions.
6. Conditional distribution of order statistics in sampling from different distributions.
7. Calculating exact moments of order statistics by using recurrence relations for arbitrary continuous distributions.
8. Calculating exact moments of order statistics by using recurrence relations for some specific distributions.
9. Distribution-free confidence intervals for population quantiles for various distributions.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- David, H. A. and Nagaraja, H. N. (2003). *Order Statistics*, 3rd ed., John Wiley & Sons.

SUGGESTIVE READINGS:

- Arnold, B.C., Balakrishnan, N. and Nagaraja H. N. (2008). *A First Course in OrderStatistics*, SIAM Publishers.
- Arnold, B.C. and Balakrishnan, N. (1989). *Relations, Bounds and Approximations forOrder Statistics*, Vol. 53, Springer-Verlag.
- Ahsanullah, M., Nevzorav, V.B. and Shakil, M. (2013). *An Introduction to OrderStatistics, Atlantis Studies in Probability and Statistics*, Vol. III. Atlantis Press.
- Shahbaz, M. Q., Ahsanullah, M., Shahbaz, S. H. and Al-Zahrani, B. M. (2016). *OrderedRandom variables: Theory and Applications*. Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE COURSE – 8B: STATISTICS IN FINANCE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistics in Finance	4	3	0	1	Class XII pass with Mathematics.	Basic knowledge of Calculus , Probability theory and Financial markets

Learning Objectives

The learning objectives include:

- To study the Financial Statistics which deals primary and secondary financial markets and the mathematical models used by these markets?
- To study to deal with the risks in financial markets

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Primary financial markets and their products such as equity, bonds and cash deposits
- Secondary financial markets and their products such as futures, forwards and options (American and European)
- Applications of stochastic models to price various secondary financial markets products.
- Hedging techniques

SYLLABUS OF GE-8B

Theory

UNIT I **(12 hours)**

Theory of interest rates

Theory of interest rates- Simple and compound interest, Nominal and effective rates of interest, interest rates of varying frequencies, continuous rates, accumulation and discount factors, relationship between interest rates and discount rates, present value, future value.

Unit II **(14 hours)**

Project appraisal and investment performance

Project appraisal and investment performance- Net present value, IRR, effect of taxation, Valuation of securities- fixed asset securities, related assets, perpetuities, bonds, coupon rates, bond-pricing formula.

Unit III **(14 hours)**

Introduction to derivative pricing

An introduction to derivative pricing- arbitrage, futures and forwards, European options- Call and put, put call parity, volatility, Black-Scholes option pricing formula, binomial model of option pricing. Hedging- delta, gamma and theta.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practical based on

1. Relationship between various interest and discount rates
2. Calculation of present values and future values of cashflows
3. To compute NPV and to obtain IRR of the investments.
4. To compute bond price and yields
5. To verify "no arbitrage" principle.
6. To price future / forward contracts
7. To price options using Black – Scholes formula.
8. Pricing of options using discrete time models.
9. Call-put parity for options.
10. Application of Greeks to hedge investment portfolios.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- David, G. L. (2015). *Investment Science*, Oxford University Press(South Asian edition)
- John C. Hull and SankarshanBasu (10th edition) Options, Future and other derivatives, PearsonIndian edition

SUGGESTIVE READINGS:

- Franke, J., Hardle, W.K. and Hafner, C.M. (2011). *Statistics of Financial Markets: An Introduction*, 3rd Ed., Springer Publications.
- Garrett S. J. (2013) *An introduction to the mathematics of Finance: A deterministic approach*, 2nd edition, Elsevier
- Ambrose Lo (2018): Derivative Pricing: A problem based primer, Chapman & Hall

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE COURSE – 8C: INTRODUCTION TO RELIABILITY THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Reliability Theory	4	3	0	1	Class XII pass with Mathematics	Knowledge of Probability Distribution and Statistical Inference

Learning Objectives

The learning objectives include:

- To describe the theoretical aspects of reliability along with their application area.
- To determine the growth in the mean life and/or the reliability of units during their research, engineering and development phase.

Learning Outcomes:

After completing this course, students should have developed a clear understanding of:

- Concept of Reliability, Maintainability and Availability.
- Various estimation procedures of reliability function(s).
- Calculate the Reliability of series and parallel systems.

SYLLABUS OF GE-8c

Theory

UNIT I **(10 hours)**

Reliability measures

Definition of Components, systems and coherent systems. Reliability functions, hazard rate function, reverse hazard rate function, residual lifetime, inactivity time, mean residual lifetime function, mean inactivity time, reliability bounds, cut and path sets.

UNIT II **(08 hours)**

Common lifetime distributions

Common lifetime distributions and their properties (Exponential, Weibull and Gamma), scale model, proportional hazard rate model, proportional reverse hazard rate model, MTTF, Bathtub failure rate, reliability importance of components.

UNIT III **(12 hours)**

Estimation of reliability functions

Various methods of reliability estimation (Classical); of some common lifetime distributions, Reliability estimation under complete and various censored samples. Stress-Strength reliability: concepts and its estimation for exponential and Weibull, k-out-of-n (exponential) and its application.

UNIT IV **(15 hours)**

Reliability systems and ageing

Reliability of series/parallel systems: introduction, series systems with identical components. Different types of redundancy. Notions of Ageing: Different ageing classes, ageing properties of common lifetime distributions, closure properties of different ageing classes under formation of coherent structures.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

Practical based on

1. Calculation of reliability function and its estimates
2. Calculation of hazard rate for various models.
3. Calculation of stress-strength reliability.
4. Various reliability and hazard rate plots.
5. Behavior of reliability estimates corresponding to sample size.
6. Practicals on ageing.
7. Other relevant problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Sinha, S.K. (1986): Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Barlow, R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston.
- Lawless, J.F. (2003): Statistical Models and Methods of Life Time Data; John Wiley.
- Bain L.J. and Max Engelhardt (1991): Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.