SUGGESTED READINGS:

- Box, G.E.P. and Tiao, G.C. (2011). Bayesian Inference in Statistical Analysis, John Wiley & Sons (reprint).
- Lee, P. M. (2012). Bayesian Statistics: An Introduction 4th edition, Wiley.
- O'Hagan, A. and Forster, J. (2010). Kendall's Advanced theory of Statistics, Volume 2B, Bayesian Inference, published by Wiley.
- Robert, C.P. (2007). The Bayesian Choice: A Decision Theoretic Foundations to Computational Implementation, Second Edition, Springer-Verlag, New York (reprint).

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 – 6 A: NON PARAMETRIC TESTING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITESOFTHE 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 be able to:

- Make distinction between Parametric and Nonparametric test and measurement scales.
- Appreciatetheroleofquantileandempiricaldistributionfunctionandassociated 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.

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; Generalized 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 Practical:

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. (2008). Comparative Statistical Inference, J. Wiley, New York.
- Berger, J.O. (2010-softcover published and 2013- eBook published). Statistical Decision Theory and Bayesian analysis, Second Edition, Springer-Verlag, New York.

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/ LABWORK (30hours):

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 to 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. (1988). Nonparametric statistics for the behavioral sciences, 2nd ed. McGraw-Hill.

SUGGESTIVE READINGS:

- Kloke, J., and McKean, J. W. (2024): Nonparametric statistical methods using R, 2nd Edition. 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

SYLLABUSOFDSE-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 gamma distributions, k-out-of-n (exponential and gamma). Mixture distribution, convolutions and competing risks: introduction, mixture of exponentials, mixture of Weibull, competing risk. Bayesian's 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/LABWORK–(30hours)

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. (1981): Statistical Theory of Reliability and Life Testing; Holt, Rinehart and Winston. (Reprint)
- Lawless, J.F. (2011): Statistical Models and Methods for Life Time Data, 2nd edition; 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 (2020): System reliability theory, Models, Statistical methods and its applications 3rd edition; Wiley.
- Zacks, S (2011 softcover published and 2012 eBook published): 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
- Developingabilitytolearngeneralizedlinearmodelsfornormalandnon-normal responses.

Learning Outcomes:
After completion of this course, students should be able to:

- 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-30Hours

List of Practical

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., & Vining, G. G. (2021). Introduction to Linear Regression Analysis (6th 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

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, A periodic Chain: Limiting Behavior, 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/LABWORK–(30hours)

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, 3rd Ed., Wiley International.
- Medhi, J. (2022) Stochastic Processes, Sixth edition 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

SUGGESTIVEREADINGS:

- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- P.G. Hoel, S.C. Port and C.J. Stone (1986): Introduction to Stochastic Processes. Waveland Press
- J.G. Kemeny, J.L. Snell and A.W. Knapp (1960): Finite Markov Chains.
- Geoffrey R, Grimmett & David R. Stirzaker (2004), Reprint: Probability and Random Processes
- Bhat, B.R. (2021). Stochastic Models: Analysis and Applications, New Age International Publishers.

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