Syllabus for Two-Year Postgraduate Programme in Statistics

Curriculum and Credit Framework (CCF) for Post-graduate Programmes
(Following NEP 2020)
With Effect from the Academic Session 2026-2027

Department of Statistics
Siksha Bhavana (Institute of Science)
Visva-Bharati (A Central University)
Santiniketan – 731235, West Bengal, India

BASIC STRUCTURE

Two-Year Postgraduate Programme in Statistics	Courses	Credits	Total Credits	Total Marks for Two-Year Postgraduate Programme in Statistics
Semester-I	STAT 401: Nonparametric Inference	4	20	500
	STAT 402: Distribution Theory	4		
	STAT 403: Applied Multivariate Analysis	4		
	STAT 404: Regression Techniques	4		
	STAT 405: Research Methodology	4		
Semester-II **(For those who want to exit after Sem-II)**	STAT 406: Operations Research	4	20	500
	STAT 407: Stochastic Process	4		
	STAT 408: Bayesian Inference	4		
	STAT 409: Categorical Data Analysis and Advanced Data Analysis Techniques	4		
	STAT 410: Project	4		
Semester-II **(For those who want to continue after Sem-II)**	STAT 406: Operations Research	4	20	500
	STAT 501: Stochastic Process	4		
	STAT 502: Bayesian Inference	4		
	STAT 503: Categorical Data Analysis and Advanced Data Analysis Techniques	4		
	STAT 504: Project	4		
Semester-III	STAT 505 Real Analysis and Measure Theory	4	20	500
	STAT 506: Time Series Analysis	4		
	STAT 507: Introductory Data Science and Machine Learning	4		
	STAT 508(1): Elective Paper : Advanced Sample Survey	4		

	OR			
	Elective Paper: STAT 508 (2): Econometrics	4		
	STAT 509: Practical based on the topics covered in STAT-506, STAT-507 and STAT-508(1) OR STAT-508(2)	4		
Semester-IV	STAT 510: Reliability Analysis	4	20	500
	STAT 511 (1): Elective Paper: Advanced Design of Experiments	4		
	OR			
	STAT 511 (2): Elective Paper: Clinical Trials and Bioassay	4		
	STAT 512: Practical based on the topics covered in STAT 510 and STAT 511(1) OR STAT 511(2)	4		
	STAT 513: Dissertation	8		
Total 4 Semesters (Two Years)	Total Courses: 20 (For 2 Year Course)	Total Credits: 80 (For 2 Year Course)		Total Marks: 2000 (For 2 Year Course)

Detailed Course Structure

1 credit = 1 hour theory class / 2 hours practical or dissertation per week in a semester, and 1 Credit = 25 mark

* Students will opt for one 'MOOCS/SWAYAM' course (NcRF level 6; 4 credits theory only; as per university rules);

alternatively, they can opt for Optional Courses which will be offered to students from other departments of Visva-Bharati. Students undergoing an MSc in Statistics will have to take these courses offered by other departments of Visva-Bharati.

Course Code	Course Type	Course title with NCrF Level	Credits	Marks	Class Hrs /week
SEMESTER-I (Two -Year PG)					
STAT401 T	Theory	Nonparametric Inference (NCrF level 6)	3	75	3
STAT 401P	*Practical*	Nonparametric Inference (NCrF level 6)	1	25	2
STAT 402	Theory	Distribution Theory (NCrF level 6)	4	100	5
STAT 403T	*Theory*	Applied Multivariate Analysis (NCrF level 6)	3	75	3
STAT 403P	Practical	Applied Multivariate Analysis (NCrF level 6)	1	25	2
STAT 404T	*Theory*	Regression Techniques (NCrF level 6)	3	75	3
STAT 404P	Practical	Regression Techniques (NCrF level 6)	1	25	2
STAT 405	*Theory*	Research Methodology (NCrF level 6)	4	100	5
		Total	**20 Credits**	**500**	25
SEMESTER-II (Two -Year PG) (For those who want to exit after Semester-II)					
STAT 406T	Theory	Operations Research (NCrF level 6)	3	75	3
STAT 406P	*Practical*	Operations Research (NCrF level 6)	1	25	2
STAT 407	Theory	Stochastic process (NCrF level 6)	4	100	5
STAT 408T	*Theory*	Bayesian Inference (NCrF level 6)	3	75	3
STAT 408P	*Practical*	Bayesian Inference (NCrF level 6)	1	25	2
STAT 409T	*Theory*	Categorical Data Analysis and Advanced Data Analysis Techniques (NCrF level 6)	3	75	3
STAT 409P	*Practical*	Categorical Data Analysis and Advanced Data Analysis Techniques (NCrF level 6)	1	25	2
STAT	*Project*	Project(NCrF level 6)	4	100	5

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		Total	**20 Credits**	**500**	
SEMESTER-II (Two -Year PG) (For those who want to continue after Semester-II)					
STAT 406T	Theory	Operations Research (NCrF level 6)	3	75	3
STAT 406P	*Practical*	Operations Research (NCrF level 6)	1	25	2
STAT 501	Theory	Stochastic process (NCrF level 6.5)	4	100	5
STAT 502T	*Theory*	Bayesian Inference (NCrF level 6.5)	3	75	3
STAT 502P	*Practical*	Bayesian Inference (NCrF level 6.5)	1	25	2
STAT 503T	*Theory*	Categorical Data Analysis and Advanced Data Analysis Techniques (NCrF level 6.5)	3	75	3
STAT 503P	*Practical*	Categorical Data Analysis and Advanced Data Analysis Techniques (NCrF level 6.5)	1	25	2
STAT 504	*Project*	Project(NCrF level 6.5)	4	100	5
		Total	**20 Credits**	**500**	
SEMESTER-III (Two-Year PG)					
STAT 505	Theory	Real Analysis and Measure Theory (NCrF level 6.5)	4	100	5
STAT 506	*Theory*	Time Series Analysis (NCrF level 6.5)	4	100	5
STAT 507	Theory	Introductory Data Science and Machine Learning (NCrF level 6.5)	4	100	5
STAT 508(1)	*Theory*	Advanced Sample Survey (NCrF level 6.5)	4	100	5
STAT 508(2)	Theory	Econometrics (NCrF level 6.5)	4	100	5
STAT 509	*Practical*	Practical based on the topics covered in STAT-506, STAT-507 and STAT-508(1) OR STAT-508(2) (NCrF level 6.5)	4	100	6
		Total	**20 Credits**	**500**	
SEMESTER-IV (Two-Year PG)					
STAT 510	*Theory*	Reliability Analysis (NCrF level 6.5)	4	100	5

STAT 511(1)	*Theory*	Advanced Design of Experiments (NCrF level 6.5)	4	100	5
STAT 511(2)	Theory	Clinical Trials and Bioassays (NCrF level 6.5)	4	100	5
STAT 512	*Practical*	Practical based on the topics covered in STAT 510 and STAT 511(1) OR STAT 511(2)	4	100	4
STAT 513	*Project*	Dissertation (NCrF level 6.5)	8	200	4
		Total	**20 Credits**	**500**	
TOTAL: 20 COURSES (For Two-Years PG Course)			**80 Credits**	**2000**	

Semester I

STAT 401T (Nonparametric Inference (Theory)) (Credit 3)

Course Objective: *This course comprises the fundamental concepts of nonparametric methods. It covers a broad range of methods and their applications and is expected to enhance students' abilities in data analysis.*

Learning Outcomes: *On completion of the course, students will be able to:*
1. Be familiar with nonparametric estimates on abstract space and their properties.
2. Construct various nonparametric test statistics, understand their exact and large sample distributions and apply them to analyze different datasets.

One-sample U-statistics, Kernel and symmetric kernel, Two-sample U-statistics, Asymptotic distribution of U-statistics. UMVUE property of U-statistics. (10L)

Linear rank statistics and their distributional properties, Rank tests, Locally most powerful rank tests. (10L)

One-sample location problem, sign test, signed-rank test, and two-sample Kolmogorov-Smirnov tests. Two-sample location and scale problems. Wilcoxon-Mann-Whitney test, median test, run test, normal score test, ARE of various tests based on linear rank statistics. Kruskal-Wallis k-sample test, Friedman's test. (20L)

SUGGESTED READINGS:

1. Gibbons, J.D. (1985): Nonparametric statistical inference, 2nd ed., Marcel Dekker, Inc.
2. Rao, C. R. (1973): Linear Statistical Inference.
3. Lehmann, E. L. (1986): Theory of Point Estimation (Student Edition).
4. Lehmann, E. L. (1986): Testing Statistical Hypothesis (Student Edition).

STAT 401P (Nonparametric Inference (Practical)) (Credit 1)

List of Practical

1. Sign test: one sample, two samples, large samples.
2. Run test: Test for randomness based on total number of runs.
3. Wilcoxon-Mann-Whitney U-test
4. Kolmogrov Smirnov test for one sample and two samples.
5. Kruskal-Wallis test

6. Friedman's test

STAT 402 (Distribution Theory) (Credit 4)

Course Objective: *This is a basic and prerequisite course for the students before studying the courses like applied multivariate analysis. It covers a vast area of advanced mathematical statistics- stretching to different multivariate inferential problems.*

Learning Outcomes: *On completion of the course, students will be able to:*

1. Understand the sampling distributions under multivariate set-up—distribution of sample mean vector, sample variance covariance matrix, sample multiple and partial correlation coefficients etc.
2. Understand the concept of Mahalanobis' distance and its distribution.

Non-central χ^2, t and F distributions. Distributions of quadratic forms under normality, Fisher-Cochran Theorem and related results. (10L)

Random Sampling from $N_p(\mu,\Sigma)$ distribution, MLE's of μ and Σ and their Stochastic independence. Central Wishart distribution (without derivation) and its properties (with proof). (15L)

Distribution of Hotelling's T^2 and Mahalanobis's D^2 with applications. (5L)

Distribution of sample multiple correlation coefficients, partial correlation coefficient and regression coefficient vector. (5L)

Multivariate Analysis of Variance (MANOVA): one way and two-way classified data with one observation per cell. (5L)

SUGGESTED READINGS:

1. Johnson, S. and Kotz, N. L. (1972): Distributions in Statistics, Vol. I, II and III, Houghton and Miffin.
2. Anderson, T. W. (1983): An Introduction to Multivariate Statistical Analysis, 2nd Ed., Wiley. 3. Johnson, R. and Wichern (1992): Applied Multivariate Statistical Analysis, prentice-Hall, 3rd Ed.
4. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979):Multivariate Analysis. Academic Press, London.

STAT 403T (Applied Multivariate Analysis (Theory)) (Credit 3)

Course Objective: *To impart the concepts and applications of various multivariate statistical techniques. To make the students understand how to analyze multivariate data using statistical theories.*

Learning Outcomes: *After this course students should be able to*

1. formulate analysis of real-life multivariate data using statistical principles along with softwares.
2. model and forecast various continuous and or discrete dependent variables depending on more than one independent variables.
3. apply various supervised and unsupervised learning methods for real-life applications.

Principal Component Analysis and Canonical Correlation Analysis: Concepts, Computation and Large sample inferences. (8L)

Factor Analysis: Concept, Factor model, estimation of factor loadings, Factor rotation, estimation of factor scores, Model fit. (5L)

Multivariate Analysis of Variance (MANOVA): one way and two-way classified data with one observation per cell. (5L)

Cluster Analysis: Concept, Proximity measures, Hierarchical and Non-hierarchical clustering techniques (6L)

Developing discriminant function considering cost factor. Fisher's method for discriminating two multivariate populations with common dispersion matrix, sample discriminant function, extension for several populations, applications of discriminant analysis. (12L)

Correspondence Analysis (2L)

Multidimension Scaling (2L)

SUGGESTED READING:

1. Giri, N. C. (1977): Multivariate Statistical Inference, Academic Press.
2. Seber, G. A. F. (1984): Multivariate Observations, Wiley.
3. Anderson, T. W. (1983): An Introduction to Multivariate Statistical Analysis, 2nd Ed., Wiley.
4. Johnson, R. and Wichern (1992): Applied Multivariate Statistical Analysis, prentice-Hall, 3rd Ed.
5. Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979): Multivariate Analysis. Academic Press, London.

STAT 403P (Applied Multivariate Analysis (Practical)) (Credit 1)

List of Practical

1. Principal component analysis
2. Factor analysis
3. Cluster analysis
4. Linear discriminant analysis
5. Multivariate analysis of variance.
6. Canonical correlation
7. Correspondence Analysis
8. Multidimension Scaling

STAT 404T (Regression Techniques (Theory)) (Credit 3)

Course Objective: *Regression Analysis is the most common statistical modeling approach used in data analysis. In this course students will learn various statistical methods for investigating functional relationships among variables. This is an applied topic that is used in various sectors like academic, company, forecasting etc. The objective is to provide the basic and advanced idea of regression analysis, so that students can be applied this modeling to solve various real life problems and draw inferences from the data.*

Learning Outcomes: *After completing the course the students will be able to:*

1. *Analyze and fit linear, polynomial and multiple linear regression models using data.*
2. *Detect and overcome the issues like model adequacy, multicollinearity and influential points.*
3. *Perform various statistical inferences related to regression analysis.*
4. *Fit the nonlinear, logistic, Poisson regression model and their inferences.*

Multiple linear regression. (5L)
Model Adequacy Checking: Residual Analysis. (5L)
Diagnostics of Leverage and influence, Variable selection and Model Building. Multicollinearity, Ridge, LASSO, Robust Regression. (10L)
Introduction to Nonlinear Regression: Parameter estimation, Statistical Inference. (5L)
Introduction to Generalized Linear Models: Logistic and Poisson Regression. (8L)
Nonparametric Regression. Use of Statistical Packages: R (7L)

SUGGESTED READING:

1. Cook, R. D. and Weisberg, S. (1982). Residual and Influence in Regression. Chapman and Hall.
2. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis. 3rd Ed. Wiley.
3. Gunst, R. F. and Mason, R. L. (1980). Regression Analysis and Its Applications – A Data Oriented Approach. Marcel and Dekker.
4. Rao, C. R. (1973). Linear Statistical Inference and Its Applications. Wiley Eastern.
5. Weisberg, S. (1985). Applied Linear Regression. Wiley.

STAT 404P (Regression Techniques (Practical)) (Credit 1)

List of Practical

1. Multiple linear regression
2. Model adequacy checking
3. Diagnostics for leverage and influence
4. Polynomial regression models
5. Multicollinearity
6. Variable selection and model building
7. Nonlinear regression

STAT 405 (Research Methodology) (Credit 4)

Course Objectives: *This course addresses the issues inherent in selecting a research problem and discuss the techniques and tools to be employed in completing a research project. This will also enable the students to prepare report writing and framing Research proposals.*

Learning Outcomes: *After this course students should be able to:*

1. *understand and comprehend the basics in research methodology and applying them in research/ project work.*
2. *select an appropriate research design.*
3. *take up and implement a research project/ study.*
4. *collect the data, edit it properly and analyze it accordingly.*
5. *demonstrate the ability to choose methods appropriate to research objectives.*

Importance of research in decision making, defining research problem and formulation of hypothesis, experimental designs, methods and techniques of data collection, data processing, statistical analysis and interpretation of data. (10L)

Sampling and sampling designs. (5L)

Multivariate analysis of data. (10L)

Technical aspects of thesis writing. (5L)

Knowledge of Computer Software e.g. R, Python, etc. Introduction to LATEX. (10L)

SUGGESTED READING:

1. Kothari, C.R.(1985): Research Methodology – Methods and Techniques (Wiley Eastern)
2. Montgomery, D. C. (1976): Design and Analysis of Experiments (Wiley)
3. Johnson, R. & Wichern (1992): Applied Multivariate Statistical Analysis (Prentice-Hall)
4. Cochran, W. G. (1984): Sampling Techniques (Wiley)

Semester II (For those who want to exit with PG Diploma)

STAT 406T (Operations Research (Theory)) (Credit 3)

Course Objective: *The objective of the course is to provide basic idea about operations research and utilizing optimization techniques as its basic tools. Use of statistical and mathematical tools in operations research and their applications to decision making process is primary concern. Role of operations research under different constraint conditions are to be studied.*

Learning Outcomes: *On completion of the course, students will be able to:*

1. Formulate the problem in operations research.
2. Establish the relationship between the variables and constraints by constructing the model.
3. Identify the possible alternative solutions and select the optimal one.
4. Install, test and establish the optimal solution.
5. Learn the tools like Linear Programming Problems, Transportation, assignment and game gamming. 6. Familiar with different inventory models.

Introduction to Operations Research, phases of O.R., model building, various types of O.R. problems. Linear Programming Problem, Mathematical formulation of the L.P.P, graphical solutions of a L.P.P. Simplex method for solving L.P.P. Charne's M-technique for solving L.P.P. involving artificial variables. Special cases of L.P.P. Concept of Duality in L.P.P: Dual simplex method. Post-optimality analysis. (16L)

Transportation Problem: Initial solution by North West corner rule, Least cost method and Vogel's approximation method (VAM), MODI's method to find the optimal solution, special cases of transportation problem. Assignment problem: Hungarian method to find optimal assignment, special cases of assignment problem. (10L)

Game theory: Rectangular game, minimax-maximin principle, solution to rectangular game using graphical method, dominance and modified dominance property to reduce the game matrix and solution to rectangular game with mixed strategy. Networking: Shortest route and minimal spanning tree problem. (7L)

Inventory Management: ABC inventory system, characteristics of inventory system. EOQ Model and its variations, with and without shortages, Quantity Discount Model with price breaks. (7L)

SUGGESTED READING:

1. Taha, H. A. (2007): Operations Research: An Introduction, 8th Edition, Prentice Hall of India.
2. Kanti Swarup, Gupta, P.K. and Manmohan (2007): Operations Research, 13th Edition, Sultan Chand and Sons.
3. Hadley, G: (2002) : Linear Programming, Narosa Publications
4. Hillier, F.A and Lieberman, G.J. (2010): Introduction to Operations Research- Concepts and cases, 9th Edition, Tata McGraw Hill

STAT 406P (Operations Research (Practical)) (Credit 1)

List of Practical

1. Mathematical formulation of L.P.P and solving the problem using graphical method, Simplex technique and Charne's Big M method involving artificial variables.
2. Identifying Special cases by Graphical and Simplex method and interpretation
   a) Degenerate solution
   b) Unbounded solution
   c) Alternate solution
   d) Infeasible solution
3. Post-optimality
   a) Addition of constraint
   b) Change in requirement vector
   c) Addition of new activity
   d) Change in cost vector
4. Allocation problem using Transportation model
5. Allocation problem using Assignment model
6. Networking problem
   a) Minimal spanning tree problem
   b) Shortest route problem
7. Problems based on game matrix \
   a) Graphical solution to m×2 / 2×n rectangular game
   b) Mixed strategy

8. To find optimal inventory policy for EOQ models and its variations
9. To solve all-units quantity discounts model

STAT 407 (Stochastic Process) (Credit 4)

Course Objective: *This course covers a vast area of advanced mathematical statistics- stretching to stochastic process.*

Learning Outcomes: *After completing the course the students will be able to understand:*

1. *Stability of stochastic process—stationarity and limiting distribution of a process*
2. *Markovian model, classifications of state under discrete time Markov model*
3. *Gambler's ruin, Random walk model*
4. *Poisson process, death and birth process, queueing theory*

Introduction to Stochastic Processes (SP): classification of SP's according to state space and time domain. Countable state Markov chains (MC's), Chapman-Kolmogorov equations, calculation of n step transition probability and its limit. Stationary distribution, classification of states, transient Mc, random walk and gambler's ruin problem. Applications from social, biological and physical sciences. (16L)

Discrete state space continuous MC: Kolomogorov-Feller differential equations. Poisson process, birth and death process. Applications to queues and storage problems. First-passage time and other problems. Wiener Process. Martingales and related results. (16L)

Renewal theory: Elementary renewal theorem and applications. Statement and applications of key renewal theorem. (8L)

SUGGESTED READING:

1. Adke, S. R. and Manjunath, S. M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.
2. Bhat, B. R. (2000): Stochastic Models: Analysis and Applications, New Age International, India.
3. Jagers, P. (1974): Branching Processes with Biological applications, Wiley
4. Karlin, S. and Taylor, H. M. (1975): A First Course in Stochastic Processes, Vol.1, Academic Press.
5. Medhi, J. (1982): Stochastic Processes, Wiley Eastern.

STAT 408T (Bayesian Inference (Theory)) (Credit 3)

Course Objective: *This course deals with Bayesian methods which have some advantages over the classical methods, viz. these provide a natural and principled way of combining prior information with data, within a solid decision theoretical framework. These also provide inferences that are conditional on the data and are exact, without reliance on asymptotic approximation. Small sample inference proceeds in the same manner as if one had a large sample. These advantages make these methods widely applicable to the data scientists. This course is designed to enlighten the students about the basics of Bayesian inferences.*

Learning Outcomes: *After completing the course the students will be able to understand:*

1. Explain in detail the Bayesian framework for data analysis and its flexibility and be able to demonstrate when the Bayesian approach can be beneficial
2. Develop, analytically describe, and implement both single and multiparameter probability models in the Bayesian framework.
3. Demonstrate the role of the prior distribution in Bayesian inference and be able to articulate the usage of non-informative priors and conjugate priors.
4. Show high level Interpretation of Bayesian Analysis Results and be able to readily perform Bayesian model evaluation and assessment.
5. Demonstrate the necessary skills to: fit hierarchical models, provide thorough technical specifications for these models.
6. Perform Bayesian computation using Markov chain Monte Carlo methods using R
7. Demonstrate how Bayesian Methods can be used to solve real world problems.
8. Communicate complex statistical ideas to a diverse audience.
9. Demonstrate the necessary research skills to form a hypothesis, collect and analyze data, and reach appropriate conclusions.

Loss functions, expected loss, decision rules, optimal decision rules, Concepts of admissibility, Bayes rules, admissibility of Bayes rules. Minimax Estimation. (8L)

Markov Chain Monte Carlo methods: Gibbs sampling for multivariate simulation, Metropolis- Hastings Algorithm. (8L)

Bayesian Linear Regression with Conjugate priors, Bayesian Model Selection, Bayesian Information Criterion (8L)

The Bayes Factor, Hierarchical Bayes Examples, Exchangeability, Hierarchical Bayesian Analysis Shrinkage and Bayesian Estimation. (8L)

Bayesian Probit and Logistic Regression (Multi-category Ordinal Response). (8L)

SUGGESTED READINGS:

1. J.O. Berger: Statistical Decision Theory and Bayesian Analysis
2. C.P. Robert: The Bayesian Choice
3. J.K. Ghosh, M. Delampady& T. Samanta: Bayesian Inference
4. P. Lee: Bayesian Statistics – An Introduction
5. Berger, J. O. (1985): Statistical Decision Theory and Bayesian Analysis, 2nd Ed., Springer.

STAT 408P (Bayesian Inference (Practical)) (Credit 1)

List of Practical

1. Gibbs sampling technique
2. Metropolis-Hastings algorithm
3. Bayesian linear regression
4. Comparing means of two groups
5. Comparing more than two groups.

STAT 409T (Categorical Data Analysis and Advanced Data Analysis Techniques (Theory)) (Credit 3)

Course Objective: *In most of the applied research problems, it is a common practice to deal with categorical variables. Besides, some of the analyses are to be made on the basis of simulated data because of the lack of proper real-life data set. This particular course is designed to give some idea about the inferences on categorical data as well as about some popular classical and Bayesian computing techniques which are appropriate in absence of proper data support.*

Learning Outcomes: *After completion of the course, the students will be able to*

1. Perform the analysis of contingency tables and fitting of generalized linear models.
2. Perform Gibbs sampling technique to simulate data from a high-dimensional posterior distribution.
3. Apply Markov Chain Monte Carlo Technique for simulation.
4. Apply Bootstrap and jackknife resampling techniques.

Categorical Data: Odds ratio, relative risk and their asymptotic distribution, Measures of ordinal association. (5L)

Generalized linear models and its properties. Logisitic and Poisson regression: logit model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters, goodness of fit, analysis of deviance, variable selection, extension to polytomous data, Introduction to Poisson regression. (10L)

Introduction to Hierarchical log-linear models. Fitting of log-linear models. (5L)

EM algorithm: applications to missing and incomplete data problems, mixture models, Application in Cluster analysis (6L)

Markov Chain Monte Carlo methods: Gibbs sampling for multivariate simulation, Metropolis- Hastings Algorithm. (6L)

Bootstrap methods: resampling paradigms, bias and standard errors, confidence intervals, bootstrapping in regression. Jackknife and cross-validation: jackknife in sample surveys, cross validation for tuning parameters. (8L)

SUGGESTED READING:

1. Agresti (1990). Categorical Data Analysis. Wiley, New York.
2. P. McCullagh and J.A. Nelder (1999). Generalized Linear Models, Second edition. Chapman and Hall, New York.
3. Robert and Casella (2004): Monte Carlo Statistical Methods, Springer
4. Efron, B. and Tibshirani, R.J. (1993) An Introduction to the Bootstrap. Chapman & Hall, New York, London.
5. J.K. Ghosh, M. Delampady & T. Samanta: Bayesian Inference

STAT 409P (Categorical Data Analysis and Advanced Data Analysis Techniques (Practical)) (Credit1)

List of Practical

1. Testing independence of attributes from contingency table.
2. Association between ordinal categorical variable.
3. Fitting of logit and probit model.
4. Poisson Regression
5. Application of EM algorithm
6. Bootstrap and Jackknife resampling techniques.
7. Gibbs sampling
8. Metropolis-Hastings algorithm.

STAT 410 (Project) (Credit 4)

Semester II (For those who want to continue with PG Degree)

STAT 406T (Operations Research (Theory)) (Credit 3)

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STAT 406P (Operations Research (Practical)) (Credit 1)

SAME AS EARLIER

STAT 501 (Stochastic Process) (Credit 4)

Course Objective: *This course covers a vast area of advanced mathematical statistics- stretching to stochastic process.*

Learning Outcomes: *After completing the course the students will be able to understand:*

1. *Stability of stochastic process—stationarity and limiting distribution of a process*
2. *Markovian model, classifications of state under discrete time Markov model*
3. *Gambler's ruin, Random walk model*
4. *Poisson process, death and birth process, queueing theory*
5. *Wiener process*

Introduction to Stochastic Processes (SP): classification of SP's according to state space and time domain. Countable state Markov chains (MC's), Chapman-Kolmogorov equations, calculation of n step transition probability and its limit. Stationary distribution, classification of states, transient Mc, random walk and gambler's ruin problem. Applications from social, biological and physical sciences. (16L)

Discrete state space continuous MC: Kolomogorov-Feller differential equations. Poisson process, birth and death process. (10L)

Renewal theory: Elementary renewal theorem and applications. Statement and applications of key renewal theorem, Delayed renewal process, Renewal reward theorem, Alternating renewal process.(8L)

Applications to queues and storage problems. M/M/1 queue, M/M/c queue, Birth-death representation of queues, Queue length and waiting time distributions, Little's formula (10L)

First-passage time and other problems. Wiener Process. Martingales and related results. (6L)

SUGGESTED READING:

1. Adke, S. R. and Manjunath, S. M. (1984): An Introduction to Finite Markov Processes, Wiley Eastern.
2. Bhat, B. R. (2000): Stochastic Models: Analysis and Applications, New Age International, India.
3. Jagers, P. (1974): Branching Processes with Biological applications, Wiley
4. Karlin, S. and Taylor, H. M. (1975): A First Course in Stochastic Processes, Vol.1, Academic Press.
5. Medhi, J. (1982): Stochastic Processes, Wiley Eastern.

STAT 502T (Bayesian Inference (Theory)) (Credit 3)

Course Objective: *This course deals with Bayesian methods which have some advantages over the classical methods, viz. these provide a natural and principled way of combining prior information with data, within a solid decision theoretical framework. These also provide inferences that are conditional on the data and are exact, without reliance on asymptotic approximation. Small sample inference proceeds in the same manner as if one had a large sample. These advantages make these methods widely applicable to the data scientists. This course is designed to enlighten the students about the basics of Bayesian inferences.*

Learning Outcomes: *After completing the course the students will be able to understand:*

1. Explain in detail the Bayesian framework for data analysis and its flexibility and be able to demonstrate when the Bayesian approach can be beneficial

2. Develop, analytically describe, and implement both single and multiparameter probability models in the Bayesian framework.
3. Demonstrate the role of the prior distribution in Bayesian inference and be able to articulate the usage of non-informative priors and conjugate priors.
4. Show high level Interpretation of Bayesian Analysis Results and be able to readily perform Bayesian model evaluation and assessment.
5. Demonstrate the necessary skills to: fit hierarchical models, provide thorough technical specifications for these models.
6. Perform Bayesian computation using Markov chain Monte Carlo methods using R
7. Demonstrate how Bayesian Methods can be used to solve real world problems.
8. Communicate complex statistical ideas to a diverse audience.
9. Demonstrate the necessary research skills to form a hypothesis, collect and analyze data, and reach appropriate conclusions.

Loss functions, expected loss, decision rules, optimal decision rules, Concepts of admissibility, Bayes rules, admissibility of Bayes rules. Minimax Estimation. (8L)

Markov Chain Monte Carlo methods: Gibbs sampling for multivariate simulation, Metropolis- Hastings Algorithm. (8L)

Bayesian Linear Regression with Conjugate priors, Bayesian Model Selection, Bayesian Information Criterion (8L)

The Bayes Factor, Hierarchical Bayes Examples, Exchangeability, Hierarchical Bayesian Analysis Shrinkage and Bayesian Estimation. (8L)

Bayesian Probit and Logistic Regression (Multi-category Ordinal Response). (8L)

Bayesian Asymptotics: Posterior consistency, Bernstein–von Mises theorem (statement), Asymptotic normality of posterior, Large sample approximation (10L)

SUGGESTED READINGS:

1. J.O. Berger: Statistical Decision Theory and Bayesian Analysis
2. C.P. Robert: The Bayesian Choice
3. J.K. Ghosh, M. Delampady& T. Samanta: Bayesian Inference
4. P. Lee: Bayesian Statistics – An Introduction
5. Berger, J. O. (1985): Statistical Decision Theory and Bayesian Analysis, 2nd Ed., Springer.

STAT 502P (Bayesian Inference (Practical)) (Credit 1)

List of Practical

1. Gibbs sampling technique
2. Metropolis-Hastings algorithm
3. Bayesian linear regression
4. Comparing means of two groups
5. Comparing more than two groups.

STAT 503T (Categorical Data Analysis and Advanced Data Analysis Techniques (Theory)) (Credit 3)

Course Objective: *In most of the applied research problems, it is a common practice to deal with categorical variables. Besides, some of the analyses are to be made on the basis of simulated data because of the lack of proper real-life data set. This particular course is designed to give some idea about the inferences on categorical data as well as about some popular classical and Bayesian computing techniques which are appropriate in absence of proper data support.*

Learning Outcomes: *After completion of the course, the students will be able to*

1. Perform the analysis of contingency tables and fitting of generalized linear models.
2. Perform Gibbs sampling technique to simulate data from a high-dimensional posterior distribution.
3. Apply Markov Chain Monte Carlo Technique for simulation.
4. Apply Bootstrap and jackknife resampling techniques.

Categorical Data: Odds ratio, relative risk and their asymptotic distribution, Measures of ordinal association. (5L)

Generalized linear models and its properties. Logisitic and Poisson regression: logit model for dichotomous data with single and multiple explanatory variables, ML estimation, large sample tests about parameters, goodness of fit, analysis of deviance, variable selection, extension to polytomous data, Introduction to Poisson regression. (10L)

Iteratively Reweighted Least Squares (IRLS), Overdispersion, Negative binomial regression, Zero-inflated models, Quasi-likelihood methods (10L)

Introduction to Hierarchical log-linear models. Fitting of log-linear models. (5L)

EM algorithm: applications to missing and incomplete data problems, mixture models, Application in Cluster analysis, Variational EM (basic idea) (6L)

Markov Chain Monte Carlo methods: Gibbs sampling for multivariate simulation, Metropolis- Hastings Algorithm. (6L)

Bootstrap methods: resampling paradigms, bias and standard errors, confidence intervals, bootstrapping in regression. Jackknife and cross-validation: jackknife in sample surveys, cross validation for tuning parameters. (8L)

SUGGESTED READING:

1. Agresti (1990). Categorical Data Analysis. Wiley, New York.
2. P. McCullagh and J.A. Nelder (1999). Generalized Linear Models, Second edition. Chapman and Hall, New York.
3. Robert and Casella (2004): Monte Carlo Statistical Methods, Springer
4. Efron, B. and Tibshirani, R.J. (1993) An Introduction to the Bootstrap. Chapman & Hall, New York, London.
5. J.K. Ghosh, M. Delampady & T. Samanta: Bayesian Inference

STAT 503P (Categorical Data Analysis and Advanced Data Analysis Techniques (Practical)) (Credit 1)

List of Practical

1. Testing independence of attributes from contingency table.
2. Association between ordinal categorical variable.
3. Fitting of logit and probit model.
4. Poisson Regression
5. Application of EM algorithm
6. Bootstrap and Jackknife resampling techniques.
7. Gibbs sampling

8. Metropolis-Hastings algorithm.

STAT 504 (Project) (Credit 4)

Semester III

STAT 505 (Real Analysis and Measure Theory) (Credit 4)

Course Objective: *The course is spitted into two parts: Real analysis and Measure theory. The objective of this course is to provide some basic and advanced ideas of real analysis and measure theory. The real analysis part mainly develops the student's analytical thinking and some prerequisite ideas of measure theory. The measure theory part helps the student to gain the knowledge about various measures. This part also develops the concept of probability and its related terms from the view of measure theory.*

Learning Outcomes: *After completing the course the students will be able to: ·*

1. *Understand various advanced ideas of real analysis like compact sets, Heine– Borel theorem etc.*
2. *Understand sequence, series of functions and their convergence.*
3. *Analyze the power series and related terms about its convergence.*
4. *Know the terms related to different measures and their importance.*
5. *Study the concept of random variables and its convergence.*
6. *Grasp the idea of characteristic functions, law of large numbers and central limit theorem.*

Real Analysis: Introduction to real numbers, Introduction to n-dimensional Euclidian space, open and closed intervals (rectangles), compact sets, Bolzano-Weirstrass theorem, Heine–Borel theorem. (8L)

Real valued functions, continuous functions, uniform continuity, sequences of functions, uniform convergence; Power series and radius of convergence. (7L)

Measure Theory: Classes of sets, fields, sigma-fields, Borel sigma-field in Rk, sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability measure, properties of a measure, Lebesgue and Lebesgue Steljes measures on Rk. (10L)

Measurable functions, Random variables, sequence of random variables, almost sure convergence, convergence in probability and convergence in distribution. Monotone convergence theorem (Statement only). Fatou's lemma (Statement only), Dominated convergence theorem (Statement only). (10L)

Borel-Cantelli Lemma (Statement only), Weak law and strong law of large numbers for iid sequences.CLT for a sequence of independent random variables under Lindeberg's condition, CLT for iid random variables. (10L)

Characteristic function, Levy's continuity theorem (statement only) (5L)

SUGGESTED READINGS:

1. Cramer, H. (1946): Mathematical Methods of Statistics, Princeton.

2. Pitman, J. (1993): Probability, Narosa publishing House. Ash, R. (1972): Real analysis and probability, Academic Press.
3. Billingsley, P. (1986): Probability and Measure, Wiley.
4. Dubley, R. M. (1989): Real Analysis and Probability, Wordsworth and Brooks/Cole.
5. Kingman, J. F. C. and Taylor, S. J. (1966); Introduction to Measure and Probability.

STAT 506 (Time Series Analysis) (Credit 4)

Course Objective: *To impart the concept of time series and how to develop statistical models to forecast a time series for practical use/planning.*

Learning Outcome: *After completion of the course, students should be able to*

1. *Distinguish time series and cross-sectional data.*
2. *Model various real-life time series data and forecast them along with the forecast errors.*

Smoothing Time series using filters.(4L)

Representation of time series as a stochastic process. Weakly and strongly Stationary process and their examples. (8L)

Ergodicity, sufficient condition for ergodicity. (4L)

Autocorrelation and partial autocorrelation functions and their properties (6L)

AR, MA, ARMA models and their properties. Estimation of ARIMA model parameters, Forecasting: minimum MSE forecast using ARIMA models (12L)

ARCH, GARCH and ARIMAX (6L)

Spectral Analysis of weakly Stationary process. Periodogram and correlogram analysis. (10L)

SUGGESTED READINGS:

1. Anderson, T.W.: The Statistical Analysis of Time series
2. Brockwell and Davis (2002): Introduction to Time series and forecasting
3. Gujarati, D.: Basic Econometrics

STAT 507 (Introductory Data Science and Machine Learning) (Credit 4)

Course Objectives: *The aim of this module is to apply quantitative modeling and data analysis techniques to the solution of real world business problems, communicate findings and effectively present results using data presentation and visualization techniques.*

Learning Outcomes: *After finishing this course the students should be able to*

1. *recognize and analyze ethical issues in business related to intellectual property, data security, integrity, and privacy.*
2. *apply ethical practices in everyday business activities and make well-reasoned ethical business and data management decisions.*
3. *demonstrate knowledge of statistical data analysis techniques utilized in business decision making.*
4. *apply principles of Data Science to the analysis of business problems. use data mining software to solve real-world problems.*
5. *apply algorithms to build machine intelligence.*

Definitions, Data wrangling, Descriptive Analytics and visualization (8L)

Feature extraction techniques (6L)

Supervised learning: Regression and Classification (10L)

Unsupervised learning (6L)

Ensemble learning (averaging, Decision tree, Logistic regression, Support Vector Machines, Bagging, Random Forest, Boosting and gradient boosting), association rules, text mining. (20L)

All the above techniques should be demonstrated using either of R or Python or both.

SUGGESTED READNIGS:

1. An Introduction to Statistical Learning- with Applications in R: Gareth James , Daniela Witten , Trevor Hastie , Springer, 2013.
2. The Elements of Statistical Learning- Data mining, Inference and Prediction: Trevor Hastie, Robert Tibshirani, Jerome Friedman, Springer, 2003
3. Machine Learning for Hackers: Drew Conway and John Myles White, O'Reilly, 2012.

STAT 508 (1) (Advanced Sample Survey) (Credit 4)

Course Objective: *Sample Survey After the introduction of the sampling schemes like Simple random Sampling, Stratified Random Sampling and Systematic Sampling in UG, this course consists of the details of the some advanced sampling schemes like Cluster Sampling, Two-stage sampling, Double Sampling, PPS sampling etc. The randomized response techniques for the surveys regarding sensitive topics are also introduced. The objective of the course is to prepare the students for all real life survey situations.*

Learning Outcomes: *After completion of the course, the students will be able to*

1. *Conduct a randomized response based survey regarding some sensitive characteristic.*
2. *Estimate the proportion of individuals having some sensitive characteristic.*
3. *Understand some basics of survey design.*
4. *Estimate the population mean/total as well as the variance of the estimators under different sampling schemes, viz Cluster Sampling, Two-stage Sampling, Double Sampling and PPS Sampling.*

Two-stage and Double Sampling and related results in estimation of population mean and total. Allocation problem in two-stage and double sampling. (15L)

Concepts of Sampling Design and Design based Inference. Rao-Blackwellization of estimators. (10L)

Unequal probability sampling: ppswr/wor methods [including Lahiri's Scheme] and related estimators of a finite population [Hansen-Hurvitz and Desraj Estimators for a general sample size and Murthy's Estimator for a sample of size 2]. Rao-Hartley and Cochran's sampling strategy and Midzuno's sampling strategy. (15L)

Randomized Response Technique. (10L)

SUGGESTED READINGS:

1. Chaudhuri, A. and Vos, J. W. E. (1988): Unified Theory and Strategies of Survey Sampling, North Holland, Amsterdam.
2. Chaudhuri, A. and Mukerjee, R. (1988): Randomized Response– Theory and Techniques, New York, Marcel Dekker Inc.
3. Cochran, W. G. (1984): Sampling Techniques, 3rd Ed. Willey.
4. Des Raj and Chandhok (1998): Sampling Theory, Narosa.
5. Mukhopadhyay, P. (1998): Small area estimation in survey sampling, Narosa

OR

STAT 508 (2) (Econometrics) (Credit 4)

Course Objectives: *To impart the knowledge of problems with violation of different assumptions while modelling real-life economic problems to solve using statistical theories and how to find solutions to those.*

Learning Outcomes: *After finishing this paper the students should be able to identify the assumption(s) being violated in a real-life (economic) dataset and to remove the issue from it and model the data for practical use.*

Introduction: Objective behind building econometric models, nature of econometrics, model building, role of econometrics, residual diagnostics, review of Gauss Markov model. (8L)

Multicollinearity: Introduction and concepts, detection of multicollinearity, consequences, tests and solutions of multicollinearity, specification error. (10L)

Generalized least squares estimation, Aitken estimators. Autocorrelation: concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation. Heteroscedastic disturbances: Concepts and efficiency of Aitken estimator with OLS estimator under heteroscedasticity. Consequences of heteroscedasticity. Tests and solutions of heteroscedasticity. (22L)

Autoregressive and Lag models, Dummy variables, Qualitative data for structural and reduced model, logit, probit model. (10L)

SUGGESTED READINGS:

1. Johnston, J. & Dinardo, J. (2005): Econometric Methods (4^{th} Ed.); McGrow-Hill
2. Greene,W.H. (2020): Econometric Analysis; Pearson Education
3. Gujrati, D.N. (2025): Basic Econometrics; McGrow-Hill

STAT 509 (Practical based on topics covered in STAT 506, STAT 507 and STAT 508(1)/STAT 508(2)) (Credit 4)

Semester IV

STAT 510 (Reliability Analysis) (Credit 4)

Course Objective: *To impart the concept of reliability and how statistical and probabilistic theories are applied to model and explain life of a mechanical component along with prediction of the same.*

Learning Outcomes: *After completing this course, students will be able to*

1. *model and explain the operation time of a mechanical component.*
2. *predict the reliability of a component, system and of a finished product.*
3. *explain the nature of the lifetime of an item as well. Reliability concepts and measures,*

Components & systems: coherent systems, reliability of the coherent systems. Cuts and paths, modular decomposition, bounds on system reliability; structural and reliability importance of components. (8L)

Life distributions, reliability function, hazard rate, common life distributions: exponential, Weibull, gamma etc. (6L)

Reliability estimation based on failure time in various censored life tests. Stress-strength reliability and its estimation. (7L)

Notions of ageing, IFR, IFRA, NBU, DMRL and NBUE and their duals, loss of memory property of the exponential distribution. Closures of these classes under formation of Coherent systems, Convolution and Mixtures. (9L)

Univariate shock models and life distribution arising out of them. Bivariate shock models, common bivariate exponential distribution and their properties. (6L)

Maintenance and replacement policies; availability of repairable systems; modeling of a repairable system by a non-homogeneous Poisson process. (8L)

Basic ideas of accelerated life testing and basic ideas of software reliability. (6L)

SUGGESTED READING:

1. Barlow R.E. and Proschan F. (1985): Statistical Theory of Reliability and Life testing:
2. Holt, Rinehart and Winston. Lawless J.F. (1982): Statistical model and Methods of Life time data, John Willey.
3. Bain L.J. and Engelhardt (1991): Statistical Analysis of Reliability and Life testing Models, Marcel Dekker.
4. Nelson, W. (1982): Applied Life Data Analysis, John Willey.

STAT 511(1) (Advanced Design of Experiments) (Credit 4)

Course Objective: *The objective of the course is to develop a systematic method to determine the relationship between factors affecting a process and the output of the process. It is used to find out cause and effect relationship. This information is needed to manage process inputs in order to optimize the output.*

Learning Outcomes: After completion of the course, the students will be able to

1. *Analyze generalized block designs.*
2. *Analyze a block design with missing observations.*
3. *Understand the purpose of confounding and analyze a factorial design with some confounded effects.*
4. *Construct Balanced Incomplete Block designs by different methods.*

Factorial experiments: 2^n, 3^n factorial experiments, illustrations, main effects and interactions, confounding and illustrations. (10L)

Split and Strip plot Analysis. (5L)

General block design and its information matrix (C). (7L)

Criteria for connectedness, balance and orthogonality. (5L:)

Intra-block analysis including estimability, best point estimates, interval estimates of estimable linear parametric functions and testing of linear hypotheses. Combined inter-intra block analysis (8L)

BIBD: Description, construction and Analysis. (15L)

SUGGESTED READING:

1. Dey, Aloke (1986): Theory of Block Designs, Wiley Eastern.
2. Dean, A. and Voss, D. (1999): Design and Analysis of Experiments, Springer.
3. Das, M. N. and Giri, N. (1979): Design and Analysis of Experiments, Wiley Eastern.
4. Joshi, D. D. (1987): Linear Estimation and Design of Experiments, Wiley Eastern.
5. Montgomery, C. D. (1976): Design and Analysis of Experiments, Wiley, New York.
6. Searle, S. R., Casella, G. and McCulloch, C. E. (1992): Variance Components, Wiley

OR

STAT 511(2) (Clinical Trials and Bioassay) (Credit 4)

Course Objective: *Bioassays are essential tools for pre-clinical research. By revealing whether a compound or biologic has the desired effect on your biological target, bioassays can drive decision-making throughout the drug discovery process, to ultimately bring new drugs to patients. This course will specially help the students who are interested to get involved in clinical research.*

Learning Outcome: *After the completion of the course, the students should be able to:*

1. *Understand the concept of basic study designs, group sequential design and adaptive designs.*
2. *Understand the notion of clinical trials.*
3. *Understand different types of biological assays.*
4. *Get involved in medical research.*

Clinical Trials: Introduction, Basic Study Design, Randomization and Blinding Ethical Issues in Clinical Trials. Sample Size, Trial Conduct and Monitoring Group sequential designs and interim stopping rules. Adaptive Designs. Issues in Data Analysis, Closeout, Reporting and Interpreting of Results. (25L)

Bioassay: Logic of biological assay; dosage response curves; quantitative and quantal responses; parallel line and slope-ratio assays; simplified estimators; sequential assays; problem of design. PK/PD Models : Compartment models and their identifiability, Numerical solutions of coupled differential equations, Mixed effects models and population PK/PD (25L)

SUGGESTED READINGS:

1. Friedman LM, Furberg CD, DeMets DL. Fundamentals of Clinical Trials. 3rd ed. Mosby-Year Book, Inc., St. Louis, 1996.
2. S.Piantadosi: Clinical Trials- A Methodologic Perspective
3. B.S.Everitt and A.Pickles: Statistical Aspects of Design & Analysis of Clinical Trial
4. J.Whitehead: The Design and Analysis of Sequential Clinical Trials
5. Z.Govindarajulu: Statistical Techniques in Bioassay
6. D.J.Finney: Statistical Methods in Bioassay

STAT 512 (Practical based on topics covered in STAT 510 and STAT 511(1)/STAT 511(2)) (Credit 4)

STAT 513 (Dissertation) (Credit 8)

INDIAN KNOWLEDGE SYSTEM (IKS) INCLUSION

Course	IKS-related Portion	Connection with Indian Knowledge System	Learning Outcome
STAT 402 – Distribution Theory	Mahalanobis Distance and its distribution; Distribution of Hotelling's T^2 and Mahalanobis' D^2.	Developed by P. C. Mahalanobis, founder of the Indian Statistical Institute. Mahalanobis distance is one of India's most influential contributions to multivariate statistics.	Students will be able to explain the theoretical foundation of Mahalanobis distance, derive its sampling distribution, and apply it to multivariate classification and statistical inference.
STAT 403 – Applied Multivariate Analysis	Principal Component Analysis, Cluster Analysis, Discriminant Analysis with applications.	These techniques extensively use Mahalanobis distance in applications such as anthropology, agriculture, biodiversity and cultural heritage studies initiated by the Indian Statistical School.	Students will be able to employ Mahalanobis-based multivariate techniques for analysing complex datasets arising from Indian socio-economic, agricultural and heritage-related studies.
STAT 405 – Research Methodology	Research design, sampling, statistical analysis, report writing.	Can incorporate Indian traditions of evidence-based knowledge generation together with the contributions of Indian statisticians to survey methodology and national planning.	Students will appreciate the role of statistical research in national development and apply scientific research methodology following ethical and evidence-based practices.
STAT 508(1) – Advanced Sample Survey	Rao–Blackwellization, Lahiri's PPS Sampling Scheme, Des Raj Estimator, Rao–Hartley–Cochran Sampling Strategy.	Contains methods developed by eminent Indian statisticians including C. R. Rao, D. B. Lahiri and Des Raj, representing major Indian contributions to sampling theory.	Students will be able to explain and implement sampling procedures developed by Indian statisticians and apply them in national surveys, official statistics and policy research.
STAT 511(1) – Advanced Design of Experiments	Balanced Incomplete Block Designs (BIBD), Block Designs.	Modern design theory includes significant contributions from R. C. Bose in combinatorial design theory.	Students will understand the theoretical basis of block designs, construct BIBDs, and appreciate India's contributions to combinatorial design theory.