Semester	**SIX**
Course	**Major**
Paper Code	**C3ST230611T**
Paper Title	**Multivariate Probability Distributions & Introduction to Asymptotic Theory**
No. of Credits	**4**
Theory / Practical /Composite	**Theory**
Classes per week	**Module I: 2 periods/week** **Module II: 2 periods/week**
Module	**2**

Course Outcomes for Module I

1. **Remember** definitions and fundamental properties of random vectors, joint, marginal and conditional distributions, mean vectors, dispersion matrices, and correlation matrices.
2. **Understand** relationships among jointly distributed random variables including multiple regression, multiple correlation, and partial correlation in a probabilistic framework.
3. **Apply** multivariate probability models and sampling distributions such as Wishart distribution and multivariate normal results to statistical problems.
4. **Analyze** structural properties and interrelationships of multinomial, multivariate normal, and Dirichlet distributions along with their sampling distributions.
5. **Evaluate** dependence structures and variability in multivariate populations using covariance matrices, correlation measures, and concentration ellipsoids.
6. **Create** multivariate probabilistic models and interpret geometric representations such as concentration ellipsoids for real data situations.

Course Outcomes for Module II

1. **Remember** concepts of sequences of random variables, modes of convergence, limit theorems, and asymptotic properties of estimators.
2. **Understand** interrelations among convergence in probability, mean square, and distribution, and describe the roles of LLN, CLT, and Slutsky's theorem.
3. **Apply** limit theorems and asymptotic results to construct tests and confidence intervals for binomial proportions and Poisson means.
4. **Analyze** large-sample behavior of estimators and distinguish between consistency, asymptotic efficiency, CAN and BAN estimators.
5. **Evaluate** estimator performance using asymptotic efficiency, relative efficiency, and large-sample properties of maximum likelihood estimators.
6. **Create** large-sample statistical inference procedures by integrating asymptotic theory with estimation and hypothesis testing frameworks.

Syllabus

Unit/Module	Content	No. of lectures	CO mapping	Cognitive levels
Module I				
Unit 1	***Random Vector:*** Probability mass/density functions, distribution function, mean vector, dispersion matrix and correlation matrix. Marginal and conditional distributions.	4	CO1	K1
Unit 2	***Relation between Jointly Distributed Random Variables:*** Definition and statement of the expressions of multiple regression, multiple correlation and partial correlation. Special cases for linear relation.	4	CO2	K2
Unit 3	***Theoretical Distributions:*** Multinomial distribution, multivariate normal distribution, Dirichlet distribution and their properties.	14	CO3 CO4	K3 K4
Unit 4	***Sampling distributions:*** Wishart distribution (definition and statement of properties). Statement of the sampling distributions for mean vector and variance-covariance matrix from multivariate normal population. Concentration Ellipsoid.	4	CO3 CO5 CO6	K3 K5 K6
Module II				
Unit 1	***Limit Theorems:*** Sequence of random variables, convergence in probability, convergence in mean square and convergence in distribution and their interrelations. Weak laws of large numbers and their applications. Slutsky's Theorem. De-Moivre-Laplace Limit Theorem. Normal approximation to Poisson distribution. Statement of central limit theorem (iid case) and its use in tests and confidence intervals for Binomial proportions and Poisson means.	14	CO1 CO2 CO3	K1 K2 K3
Unit 2	***Asymptotic Property of Estimators:*** Consistency, Asymptotic efficiency, asymptotic relative efficiency (ARE). CAN and BAN estimators. Large sample properties of maximum likelihood estimators (statement only) and their uses in testing and interval estimation.	12	CO4 CO5 CO6	K4 K5 K6

Reading/Reference list

1.	Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley.
2.	Mukhopadhyay, P. (2006) : Mathematical Statistics. 3rd Edn, Books and Allied limited, Kolkata.
3.	Applied Multivariate Analysis by Prof. Sugata Sen Roy, University of Calcutta (https://onlinecourses.swayam2.ac.in).
4.	Goon A.M., Gupta M.K., Das Gupta, B. (2005): Outline of Statistics, Vol. I & II, World Press, Calcutta.
5.	Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
6.	Miller, I. and Miller, M. (2002): John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India
7.	C.R. Rao (1983): Linear Statistical Inference and its Application. 3rd Edn, Wiley Eastern Limited.
8.	R.V. Hogg and A.T. Craig (2002): Introduction to Mathematical Statistics. 5th Edn, Pearson Education

Evaluation

	CIA: 30 End-Sem: 70 Total: 100	
Paper Structure for Semester Exam	**Module 1 (35 marks)**	**Module 2 (35 marks)**
	Short questions (5 marks each): 4 out of 6 Long questions (15 marks each): 1 out of 2	Short questions (5 marks each): 4 out of 6 Long questions (15 marks each): 1 out of 2

CO	CO Description for Module I	Cognitive levels
CO1	**Remember** definitions and fundamental properties of random vectors, joint, marginal and conditional distributions, mean vectors, dispersion matrices, and correlation matrices.	K1
CO2	**Understand** relationships among jointly distributed random variables including multiple regression, multiple correlation, and partial correlation in a probabilistic framework.	K2
CO3	**Apply** multivariate probability models and sampling distributions such as Wishart distribution and multivariate normal results to statistical problems.	K3

CO4	**Analyze** structural properties and interrelationships of multinomial, multivariate normal, and Dirichlet distributions along with their sampling distributions.	K4
CO5	**Evaluate** dependence structures and variability in multivariate populations using covariance matrices, correlation measures, and concentration ellipsoids.	K5
CO6	**Create** multivariate probabilistic models and interpret geometric representations such as concentration ellipsoids for real data situations.	K6

CO	CO Description for Module II	Cognitive levels
CO1	**Remember** concepts of sequences of random variables, modes of convergence, limit theorems, and asymptotic properties of estimators.	K1
CO2	**Understand** interrelations among convergence in probability, mean square, and distribution, and describe the roles of LLN, CLT, and Slutsky’s theorem.	K2
CO3	**Apply** limit theorems and asymptotic results to construct tests and confidence intervals for binomial proportions and Poisson means.	K3
CO4	**Analyze** large-sample behavior of estimators and distinguish between consistency, asymptotic efficiency, CAN and BAN estimators.	K4
CO5	**Evaluate** estimator performance using asymptotic efficiency, relative efficiency, and large-sample properties of maximum likelihood estimators.	K5
CO6	**Create** large-sample statistical inference procedures by integrating asymptotic theory with estimation and hypothesis testing frameworks.	K6