UNIVERSITY OF KALYANI

4-YEAR UG COURSE STRUCTURE & SYLLABUS FOR STATISTICS UNDER NEP-2020

WITH EFFECT FROM 2023-24

YEAR 1: SEMESTER **I**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-1-T ST-M-1-P	Descriptive Statistics (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-MI-1-T ST-MI-1-P	Statistical Methods (Theo & Prac)	Minor	3+1=4	4	7	3	28	12	50
ST-MU-1-T	Introductory Probability and Probability Distributions	Multi-disciplinary	3	3	10	-	35	-	45
ST-SEC-1-T	Mathematical Methods	Skill Enhancement	3	3	10	-	35	-	45
Total			16	16	45		170		215

YEAR 1: SEMESTER **II**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-2-T ST-M-2-P	Probability and Probability Distributions (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-MI-2-T ST-MI-2-P	Same as Semester I	Minor	3+1=4	4	7	3	28	12	50
ST-MU-2-T	Descriptive and Applied Statistics	Multi-disciplinary	3	3	10	-	35	-	45
AECC-1	Communicative English	Ability Enhancement	4	4	10		40		50
ST-SEC-2-P	C++ Programming (Prac)	Skill Enhancement	3	3	-	10	-	35	45
ST-SI-1	Summer Internship (Additional for Certificate/Diploma)	Internship	4	4					
Total			20(24)	20(24)	55		210		265

YEAR 2: SEMESTER **III**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-3-T ST-M-3-P	Linear Algebra and Numerical Analysis (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-MI-3-T ST-MI-3-P	Basic Probability and Probability Distributions (Theo & Prac)	Minor	3+1=4	4	7	3	28	12	50
ST-MU-3-T	Introductory Inference	Multi-disciplinary	3	3	10	-	35	-	45
ST-SEC-3-T	Research Methodology	Skill Enhancement	3	3	10	-	35	-	45
Total			16	16	45		170		215

YEAR 2: SEMESTER **IV**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-4.1-T ST-M-4.1-P	Inference-I and Sampling Distribution (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-4.2-T ST-M-4.2-P	SQC and Demography (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-MI-4-T ST-MI-4-P	Same as Semester III	Minor	4	4	10	-	40	-	50
AECC-2	MIL	Ability Enhancement	4	4	10		40		50
ST-SI-2	Summer Internship (Additional for Certificate/ Diploma)	Internship	4	4					
Total			20(24)	20(24)	50		200		250

YEAR 3: SEMESTER **V**

Course ode	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-5.1-T ST-M-5.1-P	Inference-II and Large Sample Theory (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-5.2-T ST-M-5.2-P	Survey Sampling and Official Statistics (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-MI-5.1-T ST-MI-5.1-P	Applied Statistics (Theo & Prac)	Minor	3+1=4	4	7	3	28	12	50
ST-MI-5.2-T	Sampling Distribution (Theo)	Minor	4	4	10	-	40	-	50
Total			20	20	50		200		250

YEAR 3: SEMESTER **VI**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-6.1-T ST-M-6.1-P	Multivariate Analysis and Nonparametric Techniques (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-6.2-T ST-M-6.2-P	Linear Models and Design of Experiments (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-6.3-T ST-M-6.3-P	Economic Statistics (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-OU-3/ ST-SI-3	Outreach/ Internship	Outreach/ Internship	2	2					
Total			20	20	45		180		225

YEAR 4: SEMESTER **VII**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-7.1-T	Real Analysis	Major	6	6	10	5	40	20	75
ST-M-7.2-T	Measure Theory and Probability	Major	6	4	15	-	60	-	75
ST-M-7.3-P	R Programming (Prac)	Major	6	3		15		60	75
ST-MI-7.1-T ST-MI-7.1-P	Applied Statistics (Theo & Prac)	Minor	3+1=4	3	7	3	28	12	50
ST-MI-7.2-T	Sampling Distribution (Theo)	Minor	3+1=4	4	10	-	40	-	50
Total			26	26	65		260		325

YEAR 4: SEMESTER **VIII**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-8.1-T ST-M-8.1-P	Stochastic Process (Theo & Prac)	Major	3+1=4	4	7	3	28	12	50
ST-M-8.2-T ST-M-8.2-P	Machine Learning (Theo & Prac)	Major	3+1=4	4	7	3	28	12	50
ST-M-8.3-T ST-M-8.3-P	Econometrics and Time Series (Theo & Prac)	Major	3+1=4	4	7	3	28	12	50
ST-M-8.4-T* ST-M-8.4-P*	Operations Research (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-8.5-T* ST-M-8.5-P*	Survival Analysis (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-SI-8#	Summer Internship	Project/ Dissertation	12	12					
Total			24	24					

*For Honours without Research

#For Honours with Research

DETAILED SYLLABUS

YEAR 1: SEMESTER 1

Pape: ST-M-1-T Descriptive Statistics (Theoretical) Course Type: Major

Credit 4 Marks 50

Unit 1

Statistics: Definition and scope, concepts of statistical population and sample. Data: quantitative and qualitative, Scales of measurement: nominal, ordinal, interval and ratio. Frequency distribution. Presentation: tabular and graphical, including histogram and ogives. (10L)

Unit 2

Measures of Central Tendency: Mean, Median, Mode. Measures of Dispersion: range, mean deviation, standard deviation, coefficient of variation, Gini's Coefficient, Lorenz Curve. Moments, skewness and kurtosis, Quantiles and measures based on them. Box Plot. Outlier Detection. Quantile-Quantile Plot. (12L)

Unit 3

Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares. Intra-class correlation, correlation index and correlation ratio. (8L)

Unit 4

Analysis of Categorical Data: Contingency table, association of attributes, odds ratio, Pearson's measure, Goodman- Kruskal's γ. Binary response and logistic regression. Spearman's and Kendall's Rank correlation. (10L)

Paper: ST-M-1-P Descriptive Statistics (Practical) Course Type: Major

Credit 2 Marks 25

1. Graphical representation of data.
2. Problems based on measures of central tendency.
3. Problems based on measures of dispersion.
4. Problems based on combined mean and variance and coefficient of variation.
5. Problems based on moments, skewness and kurtosis.
6. Fitting of quadratic and exponential function.
7. Karl Pearson correlation coefficient.
8. Correlation coefficient for a bivariate frequency distribution.

9. Lines of regression, angle between lines and estimated values of variables.
10. Intra-class correlation.
11. Spearman's and Kendall's rank correlation.
12. Measures of association

Suggested Reading

• Goon, A.M., Gupta, M.K. and Dasgupta, B. (2002): Fundamentals of Statistics, Vol. I, 8th Edn. The World Press, Kolkata.
• Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
• Mood, A.M., Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
• Tukey, J.W. (1977): Exploratory Data Analysis, Addison-Wesley Publishing Co.
• Agresti, A. (2010): Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
• Freedman, D., Pisani, R. and Purves, R.(2014): Statistics, 4th Edition, W. W. Norton & Company.

Paper: ST-MI-1-T Statistical Methods (Theoretical) Course Type: Minor

Credit 3 Marks 35

Unit 1
Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables, scales of measurement - nominal, ordinal, interval and ratio. Frequency distribution, Presentation**:** tabular and graphical including histogram and ogives. (10L)

Unit 2
Measures of Central Tendency: Mathematical and positional.

Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficient of variation, moments, skewness and kurtosis. (10L)

Unit 3
Bivariate data: Definition, scatter diagram, simple correlation. Partial and multiple correlation (3 variables only), rank correlation (Spearman). Simple linear regression, principle of least squares and fittingof polynomials and exponential curves. (10L)

Unit 4
Theory of attributes, consistency of data, independence and association of attributes, measures of association and contingency. (6L)

Paper: ST-MI-1-P Statistical Methods (Practical) Course Type: Minor

Credit 1 Marks 15

1. Graphical representation of data

2. Problems based on measures of central tendency

3. Problems based on measures of dispersion

4. Problems based on combined mean and variance and coefficient of variation

5. Problems based on moments, skewness and kurtosis

6. Fitting of polynomials, exponential curves

7. Karl Pearson correlation coefficient

8. Partial and multiple correlations

9. Spearman rank correlation with and without ties.

10. Correlation coefficient for a bivariate frequency distribution

11. Lines of regression, angle between lines and estimated values of variables.

12. Checking consistency of data and finding association among attributes.

Suggested Reading:

1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8thEdn. The World Press, Kolkata.

2. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics with Applications, (7th Edn.), Pearson Education,Asia.

3. Mood, A.M. Graybill, F.A. AndBoes, D.C. (2007): Introduction to the Theory of Statistics, 3rdEdn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

4. Goon A.M., Gupta M.K. and Dasgupta B. : Basic Statistics. The World Press, Kolkata.

5. Chakraborty, Arnab (2016) : Probability and Statistics. Sarat Book House

Paper: ST-MU-1-T Introductory Probability and probability distributions (Theoretical)
Course Type: Multidisciplinary Credit 3 Marks 45

Unit 1

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of probability – classical, statistical and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (12L)

Unit 2

Random Variables: Discrete and continuous random variables, p.m.f., p.d.f., c.d.f. Illustrations of random variables and its properties. Expectation, variance, moments and moment generating function. (10L)

Unit 3

Two dimensional random variables: discrete type, joint, marginal and conditional p.m.f and c.d.f., statement of properties of c.d.f, independence of variables, trinomial distribution. (8L)

Unit 4

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, exponential, beta, gamma. (10L)

Suggested Reading:

1. Hogg, R.V., Tanis, E.A. and Rao J.M. (2009): Probability and Statistical Inference, SeventhEd, Pearson Education,New Delhi.

2. Miller, Irwin and Miller, Marylees (2006): John E. Freund's Mathematical Statistics withApplications, (7th Edn.), Pearson Education,Asia.

3. Myer, P.L. (1970): Introductory Probability and Statistical Applications, Oxford & IBHPublishing, New Delhi

4. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8th Edn.The World Press, Kolkata.

5. Chakraborty, Arnab (2016): Probability and Statistics. Sarat Book House.

6. Ross, S. (2002): A First Course in Probability, Prentice Hall.

Paper: ST-SEC-1-T Mathematical Methods (Theoretical) Course Type: Skill Enhancement Credit 3 Marks 45

Unit 1

Representation of real numbers as points on a line. Algebraic, Order and Completeness properties of R (Concepts only). Bounded and unbounded sets, neighbourhood of a point, Supremum and infimum.

Functions, Countable, Uncountable sets and Uncountability of R. Sequences and their convergence,monotonic sequences, bounded sequences, squeeze theorem. Limits of some special sequences such as r^n, $(1 + 1/n)^n$ and $n^{1/n}$.

Infinite series, positive termed series and their convergence, comparison test, ratio test and root test. Absolute convergence of series, Leibnitz's test for the convergence of alternating series, Conditional convergence. (15L)

Unit 2

Review of limit, continuity and differentiability. Indeterminate form, L' Hospital's rule. Rolle's and Lagrange's Mean Value theorems. Taylor's theorem with lagrange's form of remainder (without proof). Taylor's series expansions of sin x, cos x, e^x , $(1+x)^n$ and log $(1+x)$.
Maxima and Minima of Functions. Successive Differentiation. (12L)

Unit 3

Integral Calculus: definite integral (definition). Statements of properties, Fundamental Theorem of Integral Calculus.
Improper Integral, Beta and Gamma functions: properties and relationship between them. (8L)

Unit 4

Functions of two variables and Partial Derivatives. Maxima and Minima of such Functions. Constrained Maximization and minimization, use of Lagrange Multiplier. Double Integral (intuitive-graphical approach), change of order of integration, transformation of variables and Jacobians (statement of relevant theorems and their uses) (10L)

Suggested Reading:

1. Elements of Real Analysis, Shanti Narayan and Raisinghania, S. Chand
2. Introduction to Real Analysis, 9th Edition, S. K. Mapa, Levant.
3. Principles of Mathematical Analysis, Rudin, W, McGraw Hill
4. Differential Calculus, Das, B. C. and Mukherjee , B. N., U. N. Dhur and Sons Pvt. Ltd.
5. Integral Calculus, Das, B. C. and Mukherjee , B. N., U. N. Dhur and Sons Pvt. Ltd.

YEAR 1: SEMESTER 2

Paper: ST-M-2-T Probability and Probability Distributions (Theoretical) Course Type: Major Credit 4 Marks 50

Unit 1

Probability: Introduction, random experiments, sample space, events and algebra of events.Definitions of Probability – classical, statistical, and axiomatic. Related problems. Geometric Probability. (10L)

Unit 2

Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (8L)

Unit 3

Random variables: discrete and continuous random variables, p.m.f. , p.d.f. and c.d.f., statement of properties of c.d.f. , illustrations and properties of random variables. Mathematical Expectation (discrete and continuous), Probability generating function. Moments. Moment generating function. Probability Inequalities**:** Markov & Chebyshev.

(10L)

Unit 4

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, beta and gamma. (8L)

Unit 5

Two dimensional random variables: discrete type, joint, marginal and conditional p.m.f andc.d.f., statement of properties of c.d.f, independence of variables, Correlation coefficient, Conditional expectation and variance. Trinomial distribution. (8L)

Paper: ST-M-2-P Probability and Probability Distributions (Practical) Course Type: Major Credit 2 Marks 25

1. Application problems based on Classical Definition of Probability.
2. Application problems based on Bayes' Theorem.
3. Fitting of binomial distributions for n and p = q = ½.
4. Fitting of binomial distributions for given n and p.
5. Fitting of binomial distributions after computing mean and variance.
6. Fitting of Poisson distributions for given value of lambda.
7. Fitting of Poisson distributions after computing mean.
8. Fitting of negative binomial distribution.
9. Application problems based on binomial distribution.

10. Application problems based on Poisson distribution.
11. Application problems based on negative binomial distribution**.**
12. Problems based on area property of normal distribution.

13. To find the ordinate for a given area for normal distribution.
14. Application based problems using normal distribution.
15. Fitting of normal distribution when parameters are given.
16. Fitting of normal distribution when parameters are not given.
17. Problems similar to those in 1 to 5 in cases of other continuous distributions.

Suggested Reading:

1. Chung, K.L. (1983): Elementary Probability Theory with Stochastic Process, Springer / Narosa.
2. Feller, W. (1968): An Introduction to Probability Theory & its Applications, John Wiley.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B. (1994): An Outline of Statistical Theory (Vol-1), WorldPress.
4. Parzen, E. (1972): Modern Probability Theory and its Applications, John

   Wiley .

5. Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.

6. Cacoullos, T. (1973): Exercises in Probability. Narosa.

7. Rahman, N.A. (1983): Practical Exercises in Probability and Statistics, Griffen.

8. Ross, S. (2002): A First Course in Probability, Prentice Hall.

Paper: ST-MI-2-T Same as Semester I Course Type: Minor Credit 3 Marks 35

Same as ST-MI-1-T and P

Paper: ST-MU-2-T Descriptive and Applied Statistics (Theoretical) Course Type: Multidisciplinary Credit 3 Marks 45

Unit 1
Introduction: Definition and scope of Statistics, concepts of statistical population and sample. Data: quantitative and qualitative, attributes, variables. Frequency distribution, Presentation**:** tabular and graphical including histogramand ogives. (8L)

Unit 2
Measures of Central Tendency: Mathematical and positional.

Measures of Dispersion: range, quartile deviation, mean deviation, standard deviation, coefficientof variation, moments, skewness and kurtosis. (8L)

Unit 3
Bivariate data: Definition, scatter diagram, simple correlation. Rank correlation (Spearman). Simple linear regression, principle of least squares.
Theory of attributes, consistency of data, independence and association of attributes, measures ofassociation and contingency. (10L)

Unit 4
Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve and method ofleast squares (linear and quadratic).Measurement of seasonal variationsby method of ratio to trend. (8L)

Unit 5
Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price indexnumber. Uses and limitations of index numbers. (8L)

Unit 6
Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized deathrates. Life tables: definition of its main functions and uses. Measurement of population growth: GRR, NRR. (6L)

Suggested Reading:

1. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I& II, 8thEdn. The World Press, Kolkata.

2. Goon A.M., Gupta M.K. and Dasgupta B. : Basic Statistics. The World Press, Kolkata
3. Mood, A.M. Graybill, F.A. and Boes, D.C. (2007): Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
4. Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta.
5. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4th Edition(Reprint), Sultan Chand & Sons

Paper: ST-SEC-2-P C++ Programming (Practical) Course Type: Skill Enhancement
Credit 3 Marks 45

Brief theoretical aspects, characteristics, functions etc. of C++ Programming followed by practical problems as given below:

1. Plot of a graph y = f(x)
2. Roots of a quadratic equation (with imaginary roots also)
3. Sorting of an array and hence finding median
4. Mean, Median and Mode of a Grouped Frequency Data
5. Preparing a frequency table
6. Random number generation from uniform, exponential and normal distributions
7. Compute ranks and then calculate rank correlation (without tied ranks)
8. Fitting of lines of regression (30L)

Suggested Reading:

1. Balagurusamy, E. Object-Oriented Programming with C ++, McGraw Hill.
2. Kanetkar, Y. Let Us C++, BPB Publications.

YEAR 2: SEMESTER 3

Paper: ST-M-3-T Linear Algebra and Numerical Analysis (Theoretical) Course Type: Major Credit 4 Marks 50

Linear Algebra

Unit 1
Vector: Vector space with a field of real numbers, addition and scalar multiplication of vectors, linear combination and linear independence, basis, dimension, subspace, inner-product, orthogonality and Gram-Schmidt orthogonalization process. (8L)

Unit 2
Matrix: Definition, various types of matrices, matrix operations, elementary matrices, rank of a matrix and related results, inverse of a matrix, determinants, cofactors, properties of determinants, Laplace expansion, determinant and inverse of a partitioned matrix, reduction of a matrix to normal form, triangular reduction. Homogeneous and non-homogeneous system of linear equations, consistency. Characteristic equation, eigenvalues and eigenvectors and simple related results regarding real symmetric matrices.
Quadratic forms: classification, canonical reduction, spectral decomposition. (16L)

Numerical Analysis

Unit 3
Approximation of numbers and functions, absolute and relative errors, Δ and E operators, separation of symbols using Δ and E operators.
Difference table, interpolation by Newton's forward and backward formula with error terms, Lagrange's formula, divided difference table, Newton's divided difference formula, Stirling's and Bessel's central difference interpolation formula. (10L)

Unit 4
Numerical differentiation and its applications.
Numerical integration, quadrature formula, trapezoidal, Simpson's ⅓ rd and ⅜ th rules.
Numerical solution of equations, bisection, iterative and Newton-Raphson methods in one unknown, conditions of convergence.
Stirling's approximation to n! (10L)

Paper: ST-M-3-P Linear Algebra and Numerical Analysis (Practical) Course Type: Major Credit 2 Marks 25

1. Problems on subspace and dimension of a vector space
2. Gram-Schmidt orthogonalization process
3. Finding rank and inverse of a matrix
4. Finding eigenvalues and eigenvectors of matrices

5. Problems on quadratic forms
6. Construction of difference tables and applications of interpolation formulas.
7. Applications of quadrature formulas
8. Numerical solution of equations

Suggested Reading:

1. Shanti Narayan: A Text Book on Matrices, S. Chand
2. Hadley, G: Linear Algebra, Addison Wesley, Narosa.
3. Rao, A. R. and Bhimasankaram, P.: Linear Algebra.
4. Scarborough, J. B.: Numerical Mathematical Analysis, Oxford University Press.
5. Saxena, H. C.: The Calculus of Finite Differences, S. Chand.
6. Freeman, H.: Finite Differences for Actuarial Students, Cambridge University Press.
7. Aitkinson, K.: Elementary Numerical Analysis, Wiley.

Paper: ST-MI-3-T Basic probability and Probability Distributions (Theoretical)

Course Type: Minor Credit 4 Marks 50

Unit 1

Probability: Introduction, random experiments, sample space, events and algebra of events.Definitions of Probability – classical, statistical, and axiomatic. Related problems. (10L)

Unit 2

Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (8L)

Unit 3

Random variables: discrete and continuous random variables, p.m.f. , p.d.f. and c.d.f., statement of properties of c.d.f. , illustrations and properties of random variables. Mathematical Expectation (discrete and continuous), Probability generating function. Moments. Moment generating function. Probability Inequalities**:** Markov & Chebyshev.

(10L)

Unit 4

Standard probability distributions: Binomial, Poisson, geometric, negative binomial, hypergeometric, uniform, normal, beta and gamma. (8L)

Unit 5

Two dimensional random variables: discrete type, joint, marginal and conditional p.m.f andc.d.f., statement of properties of c.d.f, independence of variables, Correlation

coefficient, Conditional expectation and variance. Trinomial distribution. (8L)

Paper: ST-MI-2-P Basic Probability and Probability Distributions (Practical) Course Type: Minor Credit 1 Marks 15

1. Application problems based on Classical Definition of Probability.
2. Application problems based on Bayes' Theorem.
3. Fitting of binomial distributions for given n and p.
4. Fitting of binomial distributions after computing mean and variance.
5. Fitting of Poisson distributions after computing mean.
6. Application problems based on binomial distribution.
7. Application problems based on Poisson distribution.
8. Application problems based on negative binomial distribution.
9. Problems based on area property of normal distribution.
10. Application based problems using normal distribution.
11. Fitting of normal distribution when parameters are not given.

Suggested Reading:

1. Chung, K.L. (1983): Elementary Probability Theory with Stochastic Process, Springer / Narosa.
2. Feller, W. (1968): An Introduction to Probability Theory & its Applications, John Wiley.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B. (1994): An Outline of Statistical Theory (Vol-1), WorldPress.
4. Parzen, E. (1972): Modern Probability Theory and its Applications, John Wiley .
5. Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.
6. Cacoullos, T. (1973): Exercises in Probability. Narosa.
7. Rahman, N.A. (1983): Practical Exercises in Probability and Statistics, Griffen.
8. Ross, S. (2002): A First Course in Probability, Prentice Hall.

Paper: ST-MU-3-T Introductory Inference Course Type: Multidisciplinary

Credit 3 Marks 45

Unit 1

Estimation of population mean, confidence intervals for the parameters of a normal distribution (one sample and two sample problems). Basic idea of significance test. Null and alternative hypothesis. Type I & Type II errors, level of significance, concept of p-value. Tests of hypotheses for the parameters of a normal distribution (one sample and two sample problems). (10L)

Unit 2

Categorical data: Tests of proportions, tests of association and goodness-of-fit using Chisquare test, Yates' correction. (5L)

Unit 3

Tests for the significance of correlation coefficient. Sign test for median, Sign test for symmetry, Wilcoxon two-sample test. (5L)

Unit 4

Analysis of variance, one-way and two-way classification. Brief exposure of three basic principles of design of experiments, treatment, plot and block. Analysis of completely randomized design, randomized complete block design. (10L)

Suggested Reading:

1. Daniel, Wayne W., Bio-statistics: A Foundation for Analysis in the Health Sciences. John Wiley (2005).
2. Goon, A.M., Gupta M.K. & Das Gupta, Fundamentals of statistics, Vol.-I & II (2005).
3. Das, M. N. & Giri, N. C.: Design and Analysis of Experiments. John Wiley.
4. Dunn, O.J Basic Statistics: A primer for the Biomedical Sciences.(1964, 1977) by John Wiley.
5. Bancroft, Holdon: Introduction to Bio-Statistics (1962) P.B. Hoebar New York.
6. Goldstein, A: Biostatistics-An introductory text (1971). The Macmillan, New York.

Paper: ST-SEC-3-T Research Methodology Course Type: Skill Enhancement

Credit 3 Marks 45

Unit 1

Introduction to research, meaning of research, role of research in important areas, process of research, types of research, Unit of analysis, characteristics of interest. Research problem as a problem of hypothesis testing. (8L)

Unit 2

Data Processing: Introduction, editing of data, coding of data, classification of data, tables as data presentation devices, graphical presentation of data (8L)

Unit 3

Data Analysis: An overview on techniques in univariate, bivariate and multivariate data Models and Model Building: role of models, types of models, objectives of modeling, model building/ model development, model validation, simulation models. (8L)

Unit 4

Formats of Reports: introduction, parts of a report, cover and title page, introductory pages, text, reference section, typing instructions, copy reading, proof reading.

Presentation of a report: introduction, communication dimensions, presentation package, audio-visual aids, presenter's poise. (8L)

Suggested Reading:

1. Kotahri, C.R (2009): Research Methodology: Methods and Techniques, 2nd Revised Ed. Reprint, New Age International Publishers

2. Lilien, Gary L. and Philip Kotler, 1983. Marketing Decision Making; A Model

Building Approach, Harper & Row, New York.

3. Shenoy, GVS, et al., (1983). Quantitative Techniques for Managerial Decision

Making, Wiley Eastern**.**

YEAR 2: SEMESTER 4

Paper: ST-M-4.1-T Inference I and Sampling Distribution (Theoretical) Course Type: Major Credit 4 Marks 50

Unit 1

Estimation: Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality and MVB estimators (statement and applications). (14L)

Unit 2

Methods of Estimation: Method of moments, method of maximum likelihood estimation, method of minimum Chi-square, basic idea of Bayes estimators. (10L)

Unit 3

Definitions of random sample, parameter and statistic, sampling distribution of a statistic, sampling distribution of sample mean, standard errors of sample mean, sample variance and sample proportion. Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region. Large sample tests, use of CLT for testing single proportion, difference of two proportions, single mean, difference of two means, standard deviation and difference of standard deviations by classical and p-value approaches. (10L)

Unit 4

Exact sampling distribution: Definition and derivation of p.d.f. of $\chi 2$ with n degrees of freedom using m.g.f., nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., cumulant generating function, mode, additive property and limiting form of $\chi 2$ distribution. Exact sampling distributions: Student's and Fishers t-distribution, Derivation of its p.d.f.,nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of t distribution. Snedecore's F-distribution: Derivation of p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance and mode. Distribution of 1/F(n1,n2). Relationship between t, F and $\chi 2$ distributions. Test of significance and confidence Intervals based on t and F distributions. (16L)

Paper: ST-M-4.1-P Inference I and Sampling Distribution (Practical) Course Type: Major Credit 2 Marks 25

List of Practical

1. Unbiased estimators (including unbiased but absurd estimators)
2. Consistent estimators, efficient estimators and relative efficiency of estimators.
3. Cramer-Rao inequality and MVB estimators

4. Sufficient Estimators – Factorization Theorem, Rao-Blackwell theorem, Complete Sufficient estimators
5. Lehman-Scheffe theorem and UMVUE
6. Maximum Likelihood Estimation

7. Estimation by the method of moments, minimum Chi-square
8. Applications of simple tests of significance
9. Applications of large sample tests of significance using CLT.

Suggested Reading:

1. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
2. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), An Outline of Statistical Theory, Vol. I, World Press, Calcutta
3. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
4. Miller, I. and Miller, M. (2002) : John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India.
5. Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. John Wiley & Sons.
6. Mood A.M, Graybill F.A. and Boes D.C,: Introduction to the Theory of Statistics, McGraw Hill.
7. Bhat B.R, Srivenkatramana T and Rao Madhava K.S. (1997) Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.
8. Snedecor G.W and Cochran W.G.(1967) Statistical Methods. lowa State University Press.

Paper: ST-M-4.2-T SQC and Demography (Theoretical) Course Type: Major
Credit 4 Marks 50

SQC

Unit 1

Quality: Definition, dimensions of quality, historical perspective of quality control and improvements starting from World War II, Quality system and standards: Introduction to ISO quality standards, Quality registration. (4L)

Unit 2

Statistical Process Control - chance and assignable causes of quality variation. Statistical Control Charts - Construction and Statistical basis of 3σ Control charts, Rational Sub-grouping.
Control charts for variables: X-bar & R-chart, X-bar & s-chart. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart.
Acceptance sampling plan: Principle of acceptance sampling plans. Single and Double sampling plan their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables. (15L)

Demography

Unit 3
Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. age and sex), IMR, Standardized death rates. (7L)

Unit 4
Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR. Graduation of mortality rates by Gompertz and Makeham's laws, logistic curve and its fitting by Rhodes' method for population forecasting. (12L)

Paper: ST-M-4.2-P SQC and Demography (Practical) Course Type: Major
Credit 2 Marks 25

1. Construction and interpretation of statistical control charts:

- X-bar & R-chart
- X-bar & s-chart
- np-chart
- p-chart
- c-chart

2. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves

3. Calculation of different birth and death rates.
4. Construction of life tables
5. Calculation of different fertility rates.
6. Graduation of mortality rates by Gompertz law.
7. Logistic curve fitting by Rhodes' method

Suggested Reading:

1. Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
2. Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
3. Mukhopadhyay, P (2011):Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd.
4. Montogomery, D. C. and Runger, G.C. (2008): Applied Statistics and Probability for Engineers, 3rd Edition reprint, Wiley India Pvt. Ltd.
5. Ehrlich, B. Harris (2002): Transactional Six Sigma and Lean Servicing, 2nd Edition, St. Lucie Press.

Paper: ST-MI-4-T & ST-MI-4-P Basic Probability and Probability Distributions (Theo & Prac) Course Type: Minor Credit 4+2 Marks 50+25

Same as Semester III

YEAR 3: SEMESTER 5

Paper: ST-M-5.1-T Inference II and Large Sample Theory (Theoretical) Course Type:

Major Credit 4 Marks 50

Unit 1

Principles of hypothesis testing: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power.
Best critical region, most powerful test, uniformly most powerful test, Neyman-Pearson Lemma (statement, proof of sufficiency part and applications to construct most powerful tests and uniformly most powerful tests). Unbiased test, Definition of UMPU test.
Likelihood ratio test, properties of likelihood ratio tests (without proof). (16L)

Unit 2

Sequential Analysis: Sequential probability ratio test (SPRT) for simple vs. simple hypotheses. Fundamental relations among α, β, A and B, determination of A and B in practice. Wald's fundamental identity and the derivation of operating characteristics (OC) and average sample number (ASN) functions, examples based on normal, Poisson and binomial distributions. (10L)

Unit 3

Notion of convergence in probability and in law, statement of Slutsky's theorem, Chebyshev's WLLN, Central Limit Theorem (CLT), use of CLT for deriving large sample tests for binomial proportions, difference of two binomial proportions, mean of a population and difference of means of two independent populations. Related confidence intervals. (8L)

Large sample standard error; derivation of large sample standard error of a function of statistics in the multiparameter situation, sample moments, standard deviation, coefficient of variation and correlation coefficient. (6L)

Unit 4

Transformation of statistics to stabilize variance: derivations of $\sin^{-1}$, square-root, logarithmic and z-transformation and their uses in large sample tests and interval estimation.

Large sample distribution of Pearsonian $\chi 2$ -statistic and its uses in test of independence, homogeneity and goodness of fit.

Paper: ST-M-5.1-P Inference II and Large Sample Theory (Practical) Course Type:

Major Credit 2 Marks 25

List of Practical
1. Probabilities of Type I and Type II errors
2. Most powerful critical region (NP Lemma)

3. Uniformly most powerful critical region
4. Unbiased critical region
5. Power curves
6. Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis
7. Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis

8. SPRT procedure
9. OC function and OC curve
10. ASN function and ASN curve
11. Large sample tests for binomial, Piosson and normal distributions
12. Uses of variance stabilizing transformations.
13. Uses of Pearsonian $\chi 2$ distributions for large sample tests.

Suggested Reading:

1. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
2.Goon A.M., Gupta M.K.: Das Gupta.B. (2005), An Outline of Statistical Theory, Vol. I, World Press, Calcutta.
3. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2ndEdn. (Reprint) John Wiley and Sons.
4. Miller, I. and Miller, M. (2002) : John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India.
5. Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. John Wiley & Sons.
6. Mood A.M, Graybill F.A. and Boes D.C,: Introduction to the Theory of Statistics, McGraw Hill.
7. Bhat B.R, Srivenkatramana T and Rao Madhava K.S. (1997) Statistics: A Beginner's Text, Vol. I, New Age International (P) Ltd.
8. Snedecor G.W and Cochran W.G.(1967) Statistical Methods. lowa State University Press.

Paper: ST-M-5.2-T Survey Sampling and Official Statistics (Theoretical) Course Type: Major Credit 4 Marks 50

Unit 1

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, definition and procedure of selecting a sample, estimates of: population mean, total and proportion, variances of these estimates, estimates of their variances and sample size determination. (10L)

Unit 2

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. Practical difficulties in allocation, estimation of gain in precision, post stratification and its performance. Systematic Sampling: Technique, estimates of population mean and total, variances of these estimates (N=nxk). Comparison of systematic sampling with SRS and stratified sampling in the presence of linear trend and corrections. (10L)

Unit 3

Introduction to Ratio and regression methods of estimation, first approximation to the population mean and total (for SRS of large size), variances of these estimates and estimates of these variances, variances in terms of correlation coefficient for regression method of estimation and their comparison with SRS. Cluster sampling (equal clusters only) estimation of population mean and its variance, comparison (with and without randomly formed clusters). Relative efficiency of cluster sampling with SRS in terms of intra class correlation. Concept of subsampling. (12L)

Unit 4

Present official statistical system in India, Methods of collection of official statistics, their reliability and limitations. Role of Ministry of Statistics & Program Implementation (MoSPI), Central Statistical Office (CSO), National Sample Survey Office (NSSO), and National Statistical Commission. Government of India's Principal publications containing data on the topics such as population, industry and finance.

(12L)

Paper: ST-M-5.2-P Survey Sampling and Official Statistics (Practical) Course Type: Major Credit 2 Marks 25

List of Practical

1. To select a SRS with and without replacement.
2. For a population of size 5, estimation of population mean, population mean square and population variance. Enumeration of all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3. For SRSWOR, estimation of mean, standard error, the sample size
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods Compare the efficiencies of above two methods relative to SRS
5. Estimation of gain in precision in stratified sampling.
6. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.
7. Ratio and Regression estimation: Calculation of the population mean or total of the population. Calculation of mean squares. Comparison of the efficiencies of ratio and regression estimators relative to SRS.
8. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS.

Suggested Reading:

1. Cochran W.G. (1984): Sampling Techniques (3rd Ed.), Wiley Eastern.
2. Sukhatme,P.V., Sukhatme,B.V. Sukhatme,S. Asok,C.(1984). Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics
3. Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
4. Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House.
5. Goon A.M., Gupta M.K. and Dasgupta B. (2001): Fundamentals of Statistics (Vol.2), World Press.
6. Guide to current Indian Official Statistics, Central Statistical Office, GOI, New Delhi.
7. WEBSITE http://mospi.nic.in/

Paper: ST-MI-5.1-T Applied Statistics (Theoretical) Course Type: Minor
Credit 3 Marks 35

Unit 1

Economic Time Series: Components of time series, Decomposition of time series- Additive and multiplicative model with their merits and demerits, Illustrations of time series. Measurement of trend by method of free-hand curve, method of semi-averages and method of least squares (linear, quadratic and modified exponential).Measurement of seasonal variations by method of ratio to trend. (10L)

Unit 2

Index numbers: Definition, Criteria for a good index number, different types of index numbers. Construction of index numbers of prices and quantities, consumer price index number. Uses and limitations of index numbers. (8L)

Unit 3

Statistical Quality Control: Importance of statistical methods in industrial research and practice. Determination of tolerance limits. Causes of variations in quality: chance and assignable. General theory of control charts, process & product control, Control charts for variables: X- bar and R-charts. Control charts for attributes: p and c-charts (8L)

Unit 4

Demographic Methods: Introduction, measurement of population, rates and ratios of vital events. Measurement of mortality: CDR, SDR (w.r.t. Age and sex), IMR, Standardized death rates. Life (mortality) tables: definition of its main functions and uses. Measurement of fertility and reproduction: CBR, GFR, and TFR. Measurement of population growth: GRR, NRR. (8L)

Paper: ST-MI-5.1-P Applied Statistics (Practical) Course Type: Minor Credit 1 Marks 15

List of Practical:

1. Measurement of trend: Fitting of linear, quadratic trend, exponential curve and

plotting of trend values and comparing with given data graphically.
2. Measurement of seasonal indices by Ratio-to-trend method and plotting of trend values and comparing with given data graphically.
3. Construction of price and quantity index numbers by Laspeyre's formula, Paasche's formula, Marshall-Edgeworth's formula, Fisher's Formula. Comparison and interpretation.
4. Construction of wholesale price index number, fixed base index number and consumer price index number with interpretation
5. Construction and interpretation of X-bar & R-chart
6. Construction and interpretation p-chart (fixed sample size) and c-chart
7. Computation of measures of mortality
8. Completion of life table
9. Computation of measures of fertility and population growth

Suggested Reading:

1.Mukhopadhyay, P. (1999): Applied Statistics, New Central Book Agency, Calcutta. 2. Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition World Press, Kolkata.
3. Gupta, S. C. and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, 4th Edition (Reprint), Sultan Chand & Sons.
4. Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.

Paper: ST-MI-5.2-T Sampling Distribution (Theoretical) Course Type: Minor
Credit 4 Marks 50

Unit 1

Definitions of random sample, parameter and statistic, sampling distribution of a statistic, sampling distribution of sample mean, standard errors of sample mean, sample variance and sample proportion. (8L)

Unit 2

Exact sampling distribution: Definition of χ^2 distribution with n degrees of freedom (d.f.), nature of p.d.f. curve for different degrees of freedom, mean, variance, m.g.f., mode, additive property. (8L)

Unit 3

Exact sampling distributions: Student's and Fishers t-distribution, their p.d.f., nature of probability curve with different degrees of freedom, mean, variance, moments and limiting form of t distribution. (8L)

Unit 4

Snedecore's F-distribution: its p.d.f., nature of p.d.f. curve with different degrees of freedom, mean, variance and mode. Distribution of $1/F(n_1,n_2)$. Relationship between t, F and χ^2 distributions. Test of significance and confidence Intervals based on t and F distributions. (8L)

Suggested Reading:

1. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), Fundamentals of Statistics, Vol. I, World Press, Calcutta.
2. Goon A.M., Gupta M.K.: Das Gupta.B. (2005), An Outline of Statistical Theory, Vol. I, World Press, Calcutta
3. Rohatgi V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
4. Dudewicz, E. J., and Mishra, S. N. (1988): Modern Mathematical Statistics. JohnWiley & Sons.

YEAR 3: SEMESTER VI

Paper: ST-M-6.1-T Multivariate Analysis and Nonparametric Techniques (Theoretical)
Course Type: Major Credit 4 Marks 50

Unit 1
Bivariate Normal (BVN) distribution: p.d.f. of BVN, properties of BVN, marginal and conditional p.d.f. of BVN distribution.
Multivariate Data: Random Vector: Probability mass/density functions, Distribution function, Mean vector & Dispersion matrix, Marginal & Conditional distributions. (8L)

Unit 2
Multivariate Normal distribution and its properties. Sampling distribution for mean vector and variance-covariance matrix. Multiple and partial correlation coefficient and their properties. (10L)

Unit 3
Applications of Multivariate Analysis: Discriminant Analysis, Principal Components Analysis and Factor Analysis. (10L)

Unit 4
Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, Kolmogrov Smirnov test for one sample, Sign tests- one sample and two samples, Wilcoxon-Mann-Whitney test, Kruskal-Wallis test. (12L)

Paper: ST-M-6.1-P Multivariate Analysis and Nonparametric Techniques (Practical)
Course Type: Major Credit 2 Marks 25

List of Practical
1. Multiple Correlation
2. Partial Correlation
3. Bivariate Normal Distribution,
4. Multivariate Normal Distribution
5. Discriminant Analysis

6. Principal Components Analysis
7. Factor Analysis
8. Test for randomness based on total number of runs,
9. Kolmogrov Smirnov test for one sample.
10. Sign test: one sample, two samples, large samples.
11. Wilcoxon-Mann-Whitney U-test
12. Kruskal-Wallis test

Suggested Reading:

1. Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rdEdn., John Wiley
2. Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
3. Kshirsagar, A.M. (1972): Multivariate Analysis, 1stEdn. Marcel Dekker.
4. Johnson, R.A. and Wichern, D.W. (2007): Applied Multivariate Analysis, 6thEdn., Pearson & Prentice Hall
5. Mukhopadhyay, P.:Mathematical Statistics.
6. Gibbons, J. D. and Chakraborty, S (2003): Nonparametric Statistical Inference. 4th Ed.

Paper: ST-M-6.2-T Linear Models and Design of Experiments (Theoretical) Course Type: Major Credit 4 Marks 50

Linear Models

Unit 1

Gauss-Markov set-up: Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance.
Regression analysis: Simple regression analysis, Estimation and hypothesis testing in case of simple and multiple regression models, Concept of model matrix and its use in estimation. (12L)

Unit 2

Analysis of variance: Definitions of fixed, random and mixed effect models, analysis of variance and covariance in one-way classified data for fixed effects models, analysis of variance and covariance in two-way classified data with one observation per cell for fixed effects models.
Model checking: Prediction from a fitted model, Violation of usual assumptions concerning normality, Homoscedasticity and collinearity, Diagnostics using quantile-quantile plots. (12L)

Design of Experiments

Unit 3

Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks.
Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency, analysis with missing observations. (12L)

Unit 4

Incomplete Block Designs: Balanced Incomplete Block Design (BIBD) – parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD. (8L)

Unit 5

Factorial experiments: advantages, notations and concepts, 2^2, $2^3 \ldots 2^n$ and 3^2 factorial experiments, design and analysis, total and partial confounding for 2^n ($n \leq 5$) and 3^2 factorial experiments in a single replicate. (10L)

Paper: ST-M-6.2-P Linear Models and Design of Experiments (Practical)

Course Type: Major Credit 2 Marks 25

List of Practical

1. Estimability when X is a full rank matrix and not a full rank matrix
3. Simple Linear Regression
4. Multiple Regression
5. Tests for Linear Hypothesis
6. Analysis of Variance for one way classified data
7. Analysis of Variance for two way classified data with one observation per cell
8. Analysis of Covariance for one way and two way classified data
9. Analysis of a CRD, RBD and LSD
10. Intra Block analysis of a BIBD
11. Analysis of 2^2 and2^3 factorial designs in CRD and RBD
12. Analysis of a completely confounded two level factorial design in 2 blocks
13. Analysis of a partially confounded two level factorial design

Suggested Reading:

1. Renchner, A. C. And Schaalje, G. B. (2008). Linear Models in Statistics (Second edition), John Wiley and Sons.
2. Kshirsagar. Linear Models
3. Scheffe, H. Analysis of Variance. Wiley.
4. Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
5. Das, M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern Ltd.
6. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8thEdn. World Press, Kolkata.
7. Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
8. Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.

Paper: ST-M-6.3-T Economic Statistics (Theoretical) Course Type: Major
Credit 4 Marks 50

Unit 1
Index numbers: Fixed-base and chain-base index numbers, tests for index numbers: time and factor reversal tests, circular test. Some important indices: consumer price index, wholesale price index – methods of construction and uses. (8L)

Unit 2
Introduction: Examples of time series from various fields, components of a times series, additive and multiplicative models. Trend and seasonal components: estimation of trend by linear filtering (simple and weighted moving averages) and curve fitting (polynomial, exponential and Gompertz), detrending, estimation of seasonal component by ratio-to-moving-average method, ratio to trend method, deseasonalization. (12L)

Unit 3
Stationary Time series: weak stationarity, autocorrelation function and correlogram. Some special Processes: moving-average (MA) process and autoregressive (AR) process of orders one and two, estimation of the parameters of AR(1) and AR(2) – Yule-Walker equations. Exponential smoothing, method of forecasting. (10L)

Unit 4
Theory and analysis of consumer demand: law of demand, price elasticity of demand, Engel curve – its different forms and properties, income elasticity of demand, estimation of Engel curves from family budget data by weighted least squares method. (10L)

Paper: ST-M-6.3-P Economic Statistics (Practical) Course Type: Major
Credit 2 Marks 25

List of Practical:

1. Calculation of price and quantity index numbers using simple and weighted average of price relatives.
2. To calculate the Chain Base index numbers.
3. To calculate consumer price index number.
4. Fitting of trend by moving average and mathematical curve fitting method.
5. Determination of seasonal indices.
6. Exponential smoothing
7. Computation of income elasticity of demand from family budget data.
8. Estimation of Engel curve.

Suggested Reading:
1. Gun, A. M., Gupta, M. K. & Dasgupta, B.: Fundamentals of Statistics vol II, World Press.
2. Mukhopadhyay, P.: Applied Statistics.
3. Prais & Houthakker: Analysis of Family Budget Data.
4. Kendall. M. G. & Stuart, A.: The Advanced Theory of Statistics, Vol III, Charles Griffin.

5. Chatfield, C.: The Analysis of Time Series – An Introduction, Chapman & Hall.
6. Allen, R. G. D.: Index Numbers in Theory and Practice, Macmillan.
7. Brockwell, P. J. & Davis, R. A.: Introduction to Time Series and Forecasting, SpringerVerlag.

YEAR 4: SEMESTER VII

Paper: ST-M-7.1-T Real Analysis (Theoretical) Course Type: Major
Credit 6 Marks 75

Unit 1

Introduction to real number, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass theorem, Heine-Borel theorem. (12L)

Unit 2

Real valued functions. Limit, continuity and uniform continuity, Differentiability of univariate and multivariate functions. Mean value Theorems, Extrema of functions. (12L)

Unit 3

Riemann Integral. Improper integrals. Riemann – Stieltjes integral. Sequence and series of functions, uniform convergence, Power series. (10L)

Unit 4

Convex functions and related properties. (5L)

Suggested Reading:

1. Apostol, T.M. (1985): Mathematical Analysis, Narosa.

2. Rudin, W. (1976): Principles of Mathematical Analysis, McGraw Hill.

3. Goldberg, R.R.: Methods of Real Analysis.

Paper: ST-M-7.2-T Measure Theory and Probability (Theoretical)

Course Type: Major Credit 6 Marks 75

Unit 1

Classes of sets, Fields, Sigma fields, Minimum Sigma field, Borel Sigma field in R, Sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability Measure, Properties of a measure. (10L)

Unit 2

Measurable functions, Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated Convergence Theorem. (8L)

Unit 3

Random variables, D.F., decomposition of D.F., Statement of correspondence theorem, Generating function and Characteristic function, Inversion theorem, Continuity theorem. (statement only) (6L)

Unit 4

Sequence of random variables, Almost sure convergence.

Borel-Cantelli lemma, Independence, Hajek-Reyni inequality, Kolmogorov inequality, strong law of large numbers.

Central Limit Theorem for iid random variables, CLT for a sequence of independent Random variables. Statements of Lindeberg-Feller & Liapounoff's theorem. (12L)

Suggested Reading:

1. A.K. Basu: Measure Theory & Probability.
2. B.R. Bhat: Modern Probability Theory.
3. P. Billingsley: Probability & Measure.
4. J.F.C. Kingman & S.J. Taylor: Introduction to Measure and Probability.
5. R.G. Laha & V.K. Rohatgi : Probability Theory.
6. R. Ash: Real Analysis and Probability.
7. C.W. Burrill: Measure Theory & Probability
8. H. Cramer: Mathematical Statistics.
9. C.R.Rao: Linear Statistical Inference and its Applications.
10. Bartle: The Elements of Integration.
11. K.R. Parthasarathy: Introduction to Probability and Measure.

Paper: ST-M-7.3-P R Programming (Practical) Course Type: Major
Credit 6 Marks 75

Basics of R programming; numerical arithmetic, simple manipulation of vectors, descriptive statistics on univariate data.

Bivariate data, factors, descriptive statistics.

Arrays and matrices, matrix operations.

Lists and data frames, *attach, detach, read.table, scan*; accessing data sets from other R packages.

Probability distributions, Q-Q plots, K-S tests, one and two sample tests.

Grouped expressions, conditional statements, loops, for and while.

Functions in R; named arguments and defaults, assignments within functions, dropping names

in a printed array, scope and class of objects, generic functions and object orientation.

Statistical models in R; Formulae for statistical models, linear model generic functions for extracting model information, ANOVA, updating fitted models, GLM, NLS, maximum likelihood models.

Graphical procedures, high level and low level plotting commands, graphical parameters.

Standard packages from R; some nonstandard statistical models. (30L)

Suggested Reading:

An Introduction to R; manual from www.r-project.org

Papers: ST-MI-7.1-T and ST-MI-7.1-P

Same as ST-MI-5.1-T and ST-MI-5.1-P

Papers: ST-MI-7.2-T

Same as ST-MI-5.2-T

YEAR 4: SEMESTER VIII

Paper: ST-M-8.1 -T Stochastic Process (Theoretical) Course Type: Major
Credit 3 Marks 35

Unit 1

Introduction to Stochastic processes, classification of Stochastic processes according to state space and time domain, Markov chain with finite and countable state space, n-step transition probability and its limit, Chapman – Kolmogorov equation, Stationary distribution, classification of states, Random Walk and gambler's ruin problem. (20L)

Unit 2

Discrete state space continuous time Markov chain: Poisson process, birth and death process.

Renewal Theory: Elementary renewal theory, statement and uses of key renewal theorem.

Branching process: Galton – Watson branching process, probability of ultimate extinction.

Continuous process: Brownian motion. (16L)

Paper: ST-M-8.1 -P Stochastic Process (Practical) Course Type: Major
Credit 1 Marks 15

List of Practical:

1. Problems on Markov Chains
2. Problems on Random Walk
3. Problems on Gambler's ruin

4. Problems on Poisson Process
5. Problems on Branching Processes

Suggested Reading:

1. J. Medhi: Stochastic Processes.
2. S.M. Ross: Introduction to Probability Models.
3. Karlin and Taylor: A First Course in Stochastic Processes.
4. B.R. Bhat: Stochastic Models.

Paper: ST-M-8.2 –T Machine Learning (Theoretical) Course Type: Major
Credit 3 Marks 35

Unit 1

Introduction to Machine Learning: Definition and types of machine learning, Overview of machine learning workflow, Introduction to popular machine learning libraries and tools. (10L)

Unit 2

Supervised Learning: Linear regression, Logistic regression, Decision trees, Random Forests, Support Vector Machines.

Unsupervised Learning: K-means clustering, Hierarchical clustering, Principal component analysis (PCA). (10L)

Unit 3

Neural Networks: Introduction to neural networks, Multilayer perceptrons, Convolutional neural networks (CNNs). (12L)

Unit 4

Model Evaluation and Selection: Metrics for evaluating machine learning models, Cross-validation, Model selection. (12L)

Paper: ST-M-8.2 –T Machine Learning (Practical) Course Type: Major
Credit 1 Marks 15

List of Practical:

1. Use of R Libraries for application problems of Unit 2

2. Use of R Libraries for application problems of Unit 3
3. Use of R Libraries for application problems of Unit 4

Suggested Reading:

1. Andrew Ng and Michael I. Jordan: Machine Learning
2. Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani: An Introduction to Statistical Learning.
3. Michael Nielsen: Neural Networks and Deep Learning.

Paper: ST-M-8.3 –T Econometrics and Time Series (Theoretical) Course Type: Major Credit 3 Marks 35

Unit 1

Nature of Econometrics. Classical General Linear Regression Model (CLRM): Specification, Estimation, Testing, and Interval Estimation. Small and Large Sample Properties of OLS estimators. The problem of multi-collinearity (MC): Effect of exact and near-exact MC estimation and testing of regression parameters. Dummy variable regression and its use in determination of seasonality. Regression Diagnostics. Simultaneous equation models: identification and estimation. (12L)

Unit 2

CLRM with non-spherical disturbance. GLS technique. Aitkin's theorem. Heteroscaedastic disturbance: Consequence on OLS estimation. Tests for heteroscaedasticity. Estimation and testing in CLRM with heteroscaedastic disturbance. (10L)

Unit 3

Smoothing of time series using filters. Representation of time series as a stochastic process. Weakly and strongly stationary processes and their examples. Autocorrelation and partial autocorrelation functions and their properties. (10L)

Unit 4

AR, MA, ARMA models and their properties. Identification, estimation and diagnostic checking of ARMA models. Forecasting. (10L)

Paper: ST-M-8.3 –P Econometrics and Time Series (Practical) Course Type: Major

Credit 1 Marks 15

1. OLS estimation
2. Testing regression parameters
3. Simultaneous equation models
4. Tests for heteroscaedasticity
5. Autocorrelated models
6. Problems relating to AR, MA and ARMA models.

Suggested Reading:

1. W.H. Greene (2002): Econometric Analysis.
2. Mittlehammer, C.R., G.G. Judge, D Miller (2001): Econometric Foundations, Cambridge.
3. Johnston & Dinardo (1990): Econometric Methods, McGraw Hill.
4. Judge, L. et al.: Theory and Practice of Econometrics.
5. Malinvaud, E. (1966): Theory of Econometrics.
6. Theil, H. (1982): Introduction to the Theory and Practice of Econometrics.

Paper: ST-M-8.4-T* Operations Research (Theoretical) Course Type: Major

Credit 4 Marks 50

Unit 1

Definition and scope of OR, Phases in OR. (4L)

Unit 2

Review of Linear Programming Problem, methods of solution, duality in LPP, transportation and assignment problem with proofs of relevant results, traveling salesman problem. (12L)

Unit 3

Inventory models, costs and distributions, EOQ model including the case with price break-ups.

Queuing models – M/M/1: (∞/FIFO) ; M/M/C : ((∞/FIFO) ; M/M/1 : (N/FIFO) models.

Sequencing models, Sequencing n jobs on two machines. (12L)

Unit 4

Elements of game theory two – person games, pure and mixed strategies, existence of solution and uniqueness of value in zero –sum games, finding solutions in 2x2, 2xm and mxn games.

Introduction to networks, determination of floats and critical paths, CPM & PERT. (12L)

Paper: ST-M-8.4-P* Operations Research (Practical) Course Type: Major

Credit 2 Marks 25

List of Practical:

Simple problems related to Unit 2 to Unit 4

Suggested Reading:

1. Goel and Mittal: Operations Research, Sultan Chand.
2. Kanti Swarup, P.K. Gupata & M.M. Singh (1985): Operations Research, Sultan Chand.
3. Philips, D.T., Ravindran, A. and Solberg, J: Operations Research, Principles and Practices.
4. Taha, H.A.: Operations Research: An Introduction, 6th Ed. 1997 Prentice–Hall of India.

Paper: ST-M-8.5-T* Survival Analysis (Theoretical) Course Type: Major

Credit 4 Marks 50

Unit 1

Survival Analysis: Functions of survival times, survival distributions and their applications: exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function. (10L)

Unit 2

Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Non-parametric methods: Kaplan-Meier method for estimating survival function and variance of the estimator. (12L)

Unit 3

Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods. Theory of independent and dependent risks. (12L)

Unit 4

Stochastic Epidemic Models: Simple epidemic models, general epidemic model definitionand concept (without derivation). Duration of an epidemic. (10L)

Paper: ST-M-8.5-P* Survival Analysis (Practical) Course Type: Major
Credit 2 Marks 25

List of Practical:

1. To estimate survival function
2. To identify type of censoring and to estimate survival time for type I censored data
3. To identify type of censoring and to estimate survival time for type II censored data
4. To identify type of censoring and to estimate survival time for progressively type Icensored data
5. Estimation of mean survival time and variance of the estimator for type I censored data
6. Estimation of mean survival time and variance of the estimator for type II censored data
7. To estimate the survival function and variance of the estimator using Non-parametric techniques with Kaplan-Meier method

Suggested Reading:

1. Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival Data Analysis, 3rdEdition, John Wiley and Sons.
2. Kleinbaum, D.G. (1996): Survival Analysis, Springer.