PERIYAR UNIVERSITY

PERIYAR PALKALAI NAGAR

SALEM – 11

M.Sc., Statistics

(SEMESTER PATTERN)

(Under Choice Based Credit System)

(For Periyar University Department)

REGULATIONS AND SYLLABUS

(Candidates admitted from 2017 - 2018 onwards)

PERIYAR UNIVERSITY
SALEM - 636 011

BRANCH II - STATISTICS

M.Sc. Degree Course in Statistics
Choice Based Credit System

(For candidates admitted during 2017-18 and onwards)

1. Objective of the Course

The course aims to inculcate knowledge on theoretical and applied aspects of Statistics in a wider spectrum. It intends to impart awareness on the importance of statistical concepts across diversified fields and to provide practical training on the applications of statistical tools in carrying out data analysis using statistical software like SAS, SYSTAT and SPSS and using the programming knowledge in R. The course curriculum is designed in such a way that the candidate on successful completion of the course will have ample opportunities to take up national level competitive examinations like CSIR NET in Mathematical Sciences, SET, Indian Statistical Service (ISS) of UPSC, etc.

2. Eligibility Criteria for Admission

A candidate who has acquired B.Sc., degree in Statistics or B.Sc., degree in Mathematics with Statistics or Mathematical Statistics as an allied / ancillary subject securing 45% of marks (40% in the case of SC/ST candidates) in aggregate in Part III shall be permitted to join the course, appear in the University Examinations and qualify for the award of M.Sc., (STATISTICS) degree after the course of study in the Department of Statistics at this University. Candidates who have acquired B. Sc., degree in Statistics shall be given preference in the admission to this course.

3. Duration of the Course and Credits

The course of the degree of M.Sc., in Statistics shall consist of two academic years comprising four semesters. During the course of study, a set of core, elective and supportive papers shall be

offered. While practical papers shall be offered in all four semesters, project / dissertation work shall be carried out by the candidate during the fourth semester. The course of study shall be based on the pattern of Choice Based Credit System (CBCS) with continuous internal assessment and comprehensive external assessment. The comprehensive external assessment shall be done as the end semester University examination. The odd semester shall begin in July and the even semester shall begin in December. Each candidate shall earn a minimum of 92 credits during the period of study. The break-up of total credits for the programme shall be as given under:

- Core Papers – Theory 13×4 Credits = 52 Credits
- Core Papers – Practical $\left.\begin{array}{l} 02\times 3\,\text{Credits} \\ 02\times 4\,\text{Credits} \end{array}\right\} = 14$ Credits
- Elective Papers 04×3 Credits = 12 Credits
- Project/Dissertation 01×8 Credits = 08 Credits
- Supportive Paper 01×4 Credits = 04 Credits
- Compulsory Paper - Human Rights and Duties 01×2 Credits = 02 Credits

4. Course Structure and Scheme of Examination

Candidates admitted to the course shall be examined in each paper under continuous internal assessment and end semester University examination. The maximum marks to each paper shall be fixed as 100. The maximum marks for continuous internal assessment and end semester University examination for theory papers shall be fixed as 25 and 75, respectively. The maximum marks for continuous internal assessment and end semester University examination for practical papers shall be fixed as 40 and 60, respectively.

All the admitted candidates shall have to carry out a project/dissertation work during the fourth semester under the supervision of the faculty of the Department of Statistics in the University. Candidates shall have to prepare and submit a report of the project/dissertation work at the end of the fourth semester. The project report/dissertation will be evaluated jointly by an External

Examiner and the Project Guide for a maximum of 40 marks. Each candidate shall appear for a Viva-Voce examination for a maximum of 20 marks, which will be conducted jointly by an External Examiner and the Project Guide.

Tests, assignments, seminars and attendance shall be the components for continuous internal assessment. A maximum of 25 marks shall be allotted under continuous internal assessment in each theory paper offered by the Department. The distribution of marks is as given under:

- Marks for Tests 10
- Marks for Assignments 05
- Marks for Seminars 05
- Attendance 05

There shall be three tests, three assignments and one seminar for each paper. The pattern of question paper for tests, the problems for assignments and the topics for seminars shall be at the discretion of the course teacher. The average of best two tests for a maximum of 10 marks, the average of all the assignments for a maximum of 5 marks, the actual marks secured by the candidate in the seminar for a maximum of 5 marks and the actual marks secured by the candidate for a maximum of 5 marks for attendance shall be taken for calculating the continuous internal assessment marks for a paper.

The distribution of continuous internal assessment marks for each core - practical paper is as given under:

Record Work	:	25 Marks
Test	:	10 Marks
Attendance	:	05 Marks

Project work shall be assessed by the guide under continuous internal assessment system to a maximum of 40 marks with 2 reviews each of 20 marks.

Course Structure and Scheme of Examination

Code	Title of the Subject	Examination				Credits
		Duration	CIA Marks	External Marks	Total Marks	
SEMESTER I						
17UPSTA1C01	Real and Complex Analysis	3	25	75	100	4
17UPSTA1C02	Measure and Probability Theory	3	25	75	100	4
17UPSTA1C03	Distribution Theory	3	25	75	100	4
17UPSTA1C04	Sampling Theory	3	25	75	100	4
	Elective I	3	25	75	100	3
17UPSTA1P01	Statistics Practical I	3	40	60	100	3
SEMESTER II						
17UPSTA1C05	Linear Algebra	3	25	75	100	4
17UPSTA1C06	Estimation Theory	3	25	75	100	4
17UPSTA1C07	Statistical Quality Control and Reliability	3	25	75	100	4
	Elective II	3	25	75	100	3
	Supportive Paper	3	25	75	100	4
17UPSTA1P02	Statistics Practical II	3	40	60	100	3
06PHR01	Human Rights and Duties	2	25	75	100	2
SEMESTER III						
17UPSTA1C08	Hypothesis Testing	3	25	75	100	4
17UPSTA1C09	Multivariate Analysis	3	25	75	100	4
17UPSTA1C10	Demographic Methods	3	25	75	100	4
17UPSTA1C11	Econometrics	3	25	75	100	4
	Elective III	3	25	75	100	3
17UPSTA1P03	Statistics Practical using R - I	3	40	60	100	4
SEMESTER IV						
17UPSTA1C12	Linear Models and Design of Experiments	3	25	75	100	4
17UPSTA1C13	Stochastic Processes	3	25	75	100	4
	Elective IV	3	25	75	100	3
17UPSTA1P04	Statistics Practical using R - II	3	40	60	100	4
17UPSTA1C14	Project/Dissertation with Viva-Voce	-	40	60	100	8
Total			**675**	**1725**	**2400**	**92**

5. List of Core, Elective and Supportive Papers

A total of 13 core theory papers, 4 core practical papers, 4 elective papers, 1 supportive paper and 1 compulsory paper shall be offered by the Department of Statistics. The list of papers is given as under:

Core Papers - Theory

S. No.	Course Code	Title of the Course	Credits
1.	17UPSTA1C01	Real and Complex Analysis	4
2.	17UPSTA1C02	Measure and Probability Theory	4
3.	17UPSTA1C03	Distribution Theory	4
4.	17UPSTA1C04	Sampling Theory	4
5.	17UPSTA1C05	Liner Algebra	4
6.	17UPSTA1C06	Estimation Theory	4
7.	17UPSTA1C07	Statistical Quality Control and Reliability	4
8.	17UPSTA1C08	Hypothesis Testing	4
9.	17UPSTA1C09	Multivariate Analysis	4
10.	17UPSTA1C10	Demographic Methods	4
11.	17UPSTA1C11	Econometrics	4
12.	17UPSTA1C12	Linear Models and Design of Experiments	4
13.	17UPSTA1C13	Stochastic Processes	4

Elective Courses

(*Note*: One paper is to be chosen from the list provided under Semester I, II, III and IV and is to offered in the respective semester)

S. No.	Course Code	Title of the Course	Credits
		SEMESTER I	
1.	17UPSTA1E01	Programming in C++	3
2.	17UPSTA1E02	Official Statistics	3
3.	17UPSTA1E03	Data Mining	3
4.	17UPSTA1E04	Actuarial Statistics	3
		SEMESTER II	
5.	17UPSTA1E05	Operations Research	3
6.	17UPSTA1E06	Simulation and Statistical Modeling	3
7.	17UPSTA1E07	Biostatistics	3
		SEMESTER III	
8.	17UPSTA1E07	Categorical Data Analysis	3
9.	17UPSTA1E08	Statistical Methods for Epidemiology	3
10.	17UPSTA1E09	Statistical Data Analysis using R	3
		SEMESTER IV	
11.	17UPSTA1E010	Applied Regression Analysis	4
12.	17UPSTA1E011	Time Series Analysis	4

13.	17UPSTA1E012	Bayesian Methods	4

Supportive Papers

S. No.	Course Code	Title of the Course	Credits
1.	17UPSTA1S01	Descriptive Statistics	3
2.	17UPSTA1S02	Computer Oriented Statistical Methods	3
3.	17UPSTA1S03	Statistics for Economics	3
4.	17UPSTA1S04	Mathematical Economics	3
5.	17UPSTA1S05	Basic Statistical Methods	3
6.	17UPSTA1S06	Statistics for Behavioral Sciences	3
7.	17UPSTA1S07	Probability and Statistics for Scientists	3
8.	17UPSTA1S08	Statistics for Researchers	3

Compulsory Paper

S. No.	Course Code	Title of the Course	Credits
1.	06PHR01	Human Rights and Duties	2

6. Award of Degree

A candidate who secures a minimum of 50% of marks in the end semester University examination and also a minimum of 50% of marks in aggregate comprising both continuous internal assessment and end semester University examination in each paper shall be declared to have passed the M.Sc., degree course in Statistics.

A candidate who secures a minimum of 75% of marks in aggregate comprising both continuous internal assessment and end semester University examination shall be declared to have passed the examination in FIRST CLASS WITH DISTINCTION, if the candidate has passed all the examination prescribed for the course in the first appearance.

A candidate who secures a minimum of 60% of marks comprising both continuous internal assessment and end semester University examination in aggregate shall be declared to have passed the examination in FIRST CLASS.

A candidate who has passed in all the papers prescribed for the course in the FIRST APPEARANCE shall be eligible for Ranking/Distinction.

7. Project and Dissertation

(a) Topic

The topic of the dissertation/project work shall be assigned to the candidate at the beginning of third semester and a copy of the same shall be submitted to the University for Approval.

(b) Number of Copies

Candidates shall prepare the dissertation / project report and submit three copies of the same for evaluation by the examiners. One copy shall be retained in the University Library, one copy shall be placed in the Department Library and the other one shall be given to the candidate after evaluation.

(c) Format for the Preparation of Dissertation / Project Report

- Title page
- Bonafide Certificate
- Acknowledgement
- Table of contents

Model Format of the Title Page

TITLE OF THE PRJOCET / DISSERTATION

Project/Dissertation Submitted in partial fulfillment of the requirement for the award of the Degree of Master of Science in

STATISTICS

(Under Choice Based Credit System)

to the Periyar University, Periyar Palkalai Nagar, Salem – 636 011

by

Students Name

Register Number

Department

Year

Model Format of the Certificate

Certificate

This is to certify that the dissertation / project work entitled '.....' submitted in partial fulfillment of the requirement for the award of the Degree of Master of Science in **STATISTICS (Under Choice Based Credit System)** to the Periyar University, Periyar Palkalai Nagar, Salem is a record of bonafide research work carried out by him / her under my supervision and guidance and that no part of the dissertation/project work has been submitted for the award of any degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journals or magazines.

Date:

Place: Signature of the Guide

Counter signed:

Signature of the Head of the Department

Model Table of Contents

Chapter No.	Title	Page No.
1.	Introduction	
2.	Review of Literature	
3.	Results	
4.	Summary	
5.	References	

8. Pattern of Question Paper for the End Semester Comprehensive Examination

The question paper shall consist of three sections. While there shall be no choice in Section A, internal choice (either or type) shall be given in Section B and Section C. In Section A, there shall be one question from each of the five units. In Sections B and C, there shall be one question with internal choice (either/or type) from each of the five units.

Section A - (5 x 2 = 10 marks) (one question from each unit)

Section B - (5 x 5 = 25 marks) (one question from each unit with internal choice)

Section C – (5 x 8 = 40 marks) (one question from each unit with internal choice)

M.Sc., Degree Examination
Branch II – Statistics
SUBJECT

Time: 3 Hours Max. Marks: 75

Section - A (5 × 2 =10)
Answer *ALL* questions
Each question carries *TWO* marks

1. from Unit I
2. from Unit II
3. from Unit III
4. from Unit IV
5. from Unit V

Section - B (5 × 5 = 25 Marks)
Answer *ALL* questions
Each question carries *FIVE* marks

6. (a) from Unit I

(OR)

(b) from Unit I

7. (a) from Unit II

(OR)

(b) from Unit II

8. (a) from Unit III

(OR)

(b) from Unit III

9. (a) from Unit IV

(OR)

(b) from Unit IV

10. (a) from Unit V

(OR)

(b) from Unit V

Section – C (5 × 8 = 40 marks)
Answer *ALL* questions
Each question carries *EIGHT* marks

11. (a) from Unit I

(OR)

(b) from Unit I

12. (a) from Unit II

(OR)

(b) from Unit II

13. (a) from Unit III

(OR)

(b) from Unit III

14. (a) from Unit IV

(OR)

(b) from Unit IV

15. (a) from Unit V

(OR)

(b) from Unit V

Paper I

Real and Complex Analysis

Unit I

Introduction to *n* - dimensional Euclidean space and metric space – Point set topology: Interior point, open and interior sets - Limit point - Closed set. Countability, supremum and infimum of sets of real numbers – Bolzano-Weirstrass theorem.

Unit II

Convergence of sequences and series of real numbers – absolute and conditional convergence – Point - wise and uniform convergence – Tests for absolute, conditional and uniform convergence – Properties of uniform convergence.

Unit III

Real valued functions - Limits and continuity and uniform continuity – Differentiability – Maxima and Minima of functions – Mean value theorem, Taylor's theorem – Functions of several variables.

Unit IV

Rieman-Stieljtes (R-S) intergral. Upper and lower R-S integrals. Necessary and sufficient condition for R-S integrability. Algebra of R-S integrable functions. Class of R-S integrable functions. Integration by parts. First mean value theorem and Cauchy's mean value theorem for R-S integrals.

Unit V

Complex Analysis: Algebra of complex numbers, the complex plane, polynomials, power series. Analytic functions, Cauchy - Riemann equations. Contour integral, Cauchy's theorem, Cauchy's integral formula.

Books for Study

1. Ajit Kumar and Kumaresan, S. (2014). A Basic Course in Real Analysis, Chapman and Hall/CRC Press.
2. Bartle, R. G., and Sherbert, D. R. (2000). Introduction to Real Analysis, Third Edition, John Wiley & Sons, New York.
3. Malik, S.C., and Arora, S. (2009). Mathematical Analysis, Second Edition, New Age International, New Delhi.
4. Rudin, W. (1985). Principles of Mathematical Analysis, McGraw-Hill, New York.
5. Sharma, J. N. (2014). Functions of a Complex Variable, Forty Ninth Edition, Krishna Prakashan Media (P) Ltd, India.

Books for Reference

1. Arora, S. (1988). Real Analysis, Satya Prakashan Mandir, New Delhi.
2. Apostol, T. M. (1986). Mathematical Analysis, Second Edition, Addison-Wesley, New York (Twentieth Reprint, 2002).
3. Bilodeau, G. G., Thie, P. R., and Keough, G. E. (2010). An Introduction to Analysis, Jones and Barlet Publishers, New Delhi.

4. Goldberg, R. R. (1976). Methods of Real Analysis, Oxford & IBH Publishing Company, New Delhi.

Paper II

Measure and Probability Theory

Unit I

Classes of sets - ring - field - σ-field - minimal σ-field - Borel field - sequences of sets - limit inferior and limit superior of sequences of sets - Measurable space - measure space – properties of measure - Lebesgue measure and Lebesgue-Stieltjes measure - Probability space - probability measure – properties of probability measure.

Unit II

Measurable function – random variable – distribution function – discrete and continuous random variables – decomposition of distribution functions - Expectation and moments – properties – generating functions - Chebyshev's, Markov's, Holder's, Jensen's and Minkowski's inequalities - Conditional probability and conditional expectation – properties and applications. Product space - Fubini's theorem (statement only) and its applications.

Unit III

Modes of convergence – convergence in probability, convergence in distribution, convergence in r^{th} mean, almost sure convergence and their interrelationships. Weak and complete convergences of distribution functions – Helly's first and second limit theorems (statement only) and their applications.

Unit IV

Characteristic Function: Definition and Properties - Uniqueness Theorem - Inversion Formula – Problems. Khintchine - Bochner's theorem (statement only). Independence of random variables – Borel-Cantelli lemma – Borel 0-1 law, Kolmogorov's 0-1 law. Kolmogorov's inequality – Glivenko-Cantelli theorem (statement only).

Unit V

Law of large numbers: Bernoulli's and Khintchine's weak law of large numbers, Kolmogorov's strong law of large numbers. Simple problems. Central limit theorems: De Moivre-Laplace central limit theorem, Lindeberg-Levy's central limit theorem, Liaponov's central limit theorem – Lindeberg-Feller's central limit theorem (statement only). Applications.

Books for Study

1. Ash, B.R. (1972): Real Analysis and Probability. Academic Press, New York.
2. Bhat, B.R.(1999): Modern Probability Theory (Third Edition). New Age International, New Delhi.(Reprint 2004)
3. Billingsley, P. (2012): Probability and Measure (Third Edition). John Wiley & Sons, New York.
4. Chow, Y.S. and Teicher, H. (2012): Probability Theory: Independence, Interchangeability, Martingales (Second Edition). Springer Limited.
5. Feller, W. (2008): An Introduction to Probability Theory and Its Applications, Volume I (Third Edition), John Wiley & Sons, New York.
6. Feller, W. (1971): An Introduction to Probability Theory and Its Applications, Volume II, John Wiley & Sons, New York. (Reprint, 2008).
7. Loe've, M. (1978): Probability Theory (Fourth Edition). Springer-Verlag, New York.

8. Rana, I.K. (2005): An Introduction to Measure and Integration (Second Edition). Morgan & Claypool.
9. Rohatgi, V.K. and Saleh, A.K.Md.E. (2011): An Introduction to Probability and Statistics (Second Edition). John Wiley & Sons, New York.
10. Ross, S.M (2010). A First Course in Probability. Pearson Prentice Hall.

Paper III

Distribution Theory

Unit I

Basic distribution theory – Joint, marginal and conditional probability mass functions and probability density functions. Standard distributions: Binomial, Poisson, multinomial and Normal probability distributions. Bivariate normal distribution – Properties and relationships.

Unit II

Functions of random variables and their distributions – Methods of finding distributions: Cumulative Distribution Function - Jacobian of transformation - Characteristic Function and Moment Generating Function. Mathematical Expectation and Conditional expectation.

Unit III

Geometric, Negative binomial, Truncated binomial, Truncated Poisson, Power series and Logarithmic distributions – Properties and relationships.

Unit IV

Exponential, Laplace, logistic, log-normal, beta, gamma, Cauchy and compound Poisson distribution. Sampling distributions - Central-*t*, Central-*F*, Central chi-square distributions – Properties and relationships.

Unit V

Non – central *t* - non–central chi-square - non-central *F* distributions and their properties. Order statistics: Distribution of rth order statistics – Joint distribution of two or more order statistics - Distribution of sample range and median.

Books for Study

1. Dudewicz, E.J., and Mishra, S. N. (1988). Modern Mathematical Statistics, John Wiley & Sons, New York.
2. Mood, A.M., Graybill, F.A., and Boes, D.C. (1974). Introduction to the Theory of Statistics, Third Edition, McGraw-Hill International Edition.
3. Mukhopadhyay, P. (2002). Mathematical Statistics, Book and Allied Publishers, New Delhi.
3. Rao, C. R. (2009). Linear Statistical Inference and Its Applications, Second Edition, John Wiley and Sons, New York.
4. Rohatgi, V.K., and Saleh, A. K. Md. E. (2011). An Introduction to Probability and Statistics Second Edition, John Wiley and Sons, New York.

Books for Reference

1. Johnson, N. L., Kemp, A.W., and Kotz, S. (2005). Univariate Discrete Distributions, Third Edition, John Wiley and Sons, New York.
2. Johnson, N. L., Kotz, S., and Balakrishnan, N. (2004). Continuous Univariate Distributions. Vol. I, John Wiley and Sons (Asia), Singapore.
3. Johnson, N. L., Kotz, S., and Balakrishnan, N. (2014). Continuous Univariate Distributions, Vol. II. John Wiley and Sons (Asia), Singapore.

4. Karian, Z.A., and Dudewicz, E.J. (2011). Handbook of Fitting Statistical Distributions with R, Chapman and Hall.

Paper IV

Sampling Theory

Unit I

Population and Sample – Census and sample survey – sampling – sampling unit, sampling frame, sampling distribution, standard error, questionnaire and schedule, sampling design – sampling and non-sampling errors – non-response and its effects – sample surveys – principles of sample survey - principal steps in sample survey - limitations of sampling – NSSO/CSO in India.

Unit II

Simple Random Sampling (with and without replacement): Notations and terminology- Estimates of population total, mean and their variances and standard errors - determination of sample size - pooling of estimates – confidence limits – simple random sampling of attributes – interpenetrating sub-samples.

Unit III

Stratified random sampling: Estimates of population total, mean and their variances - Related properties – Allocation of sample sizes – Neyman's proportional and optimum allocations - Comparison of stratified sampling with simple random sampling - Estimation of proportion under stratified random sampling.

Unit IV

Systematic sampling: Estimates of population total, mean, and their variances and standard errors – systematic sampling with linear trend – comparison of systematic sampling with stratified and simple random sampling – circular systematic sampling - Two stage sampling with equal number of second stage units and cluster sampling.

Unit V

Varying Probability Sampling: PPS sampling (with and without replacement) – gain due to PPS sampling – stratified PPS – selection procedures – ordered and unordered estimates – Desraj, Horwitz – Thompson and Murthy's estimates. Ratio Estimate – Methods of estimation, approximate variance of the Ratio Estimate - Regression Estimators – Difference Estimators, Regression Estimators in Stratified Sampling - Double sampling.

Books for Study

1. Cochran, W.G. (2007). Sampling Techniques, Third Edition, John Wiley & Sons, New Delhi.
2. Desraj (1976). Sampling Theory. Tata McGraw Hill, New York. (Reprint 1979).
3. Murthy, M. N. (1977). Sampling Theory and Methods. Statistical Publishing Society, Calcutta.
4. Singh, D., and Choudhary, F.S. (1977). Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd, New Delhi.(Reprint 1986).

Books for Reference

1. Ardilly, P., and Yves T. (2006). Sampling Methods: Exercise and Solutions. Springer.
2. Sukhatme, P.V., and Sukhatme, B.V. (1970). Sampling Theory Surveys with Applications, Second Edition, Iowa State University Press.
3. Sukhatme, P.V., and Sukhatme, B.V. (1958). Sampling Theory Surveys with Applications. Indian Society of Agricultural Statistics, New Delhi.

4. Thompson, S.K. (2012). Sampling, John Wiley and Sons, New York.

Paper V

Linear Algebra

Unit I

Finite dimensional vector space, subspace, basis and dimension – Linear dependence and independence - Linear transformations of vectors and matrices – Rank of a matrix, null space and nullity of matrix.

Unit II

Inner product for real and complex spaces – Properties of inner product, inner product space. Orthogonality of vectors and matrices – Orthonormalization process.

Unit III

Characteristic roots and characteristic vectors. Cayley-Hamilton theorem. Minimum polynomial, similar matrices, algebraic and geometric multiplicities of a characteristic root. Spectral decomposition of a real symmetric matrix.

Unit IV

Quadratic forms. Congruent transformations, congruence of symmetric matrices. Canonical reduction and orthogonal reduction of real quadratic forms. Nature of quadratic forms. Sylvester's law of inertia. Simultaneous reduction of a pair of quadratic forms.

Unit V

Generalized inverse of matrix. Properties and computation of g - inverses. Moore-Penrose inverse. Vector and matrix derivatives.

Books for Study

1. Ayres, F. Jr. (1965). Modern Abstract Algebra, First Edition, McGraw-Hill Professional Publishing.
2. Hoffman, K., and Kunze, R. (1975). Linear Algebra, Second Edition, Prentice Hall of India, New Delhi.
3. Kumaresan, S. (2000). Linear Algebra: A Geometric Approach, PHI Learning.
4. Rao, A. R., and Bhimasankaram, P. (2000). Linear Algebra, Second Edition, Hindustan Book Agency, Hyderabad.
5. Vasishta, A. R. (2005). Matrices. Krishna Prakashan Mandir, New Delhi.

Books for Reference

1. Graybill, F.A. (1983). Matrices and Applications in Statistics, Wadsworth Publishing Company, Belmont, California, USA.
2. Hohn, F.E. (1971). Elementary Matrix Algebra, Amerind Publishing Co. Pvt. Ltd., New Delhi.
3. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, Wiley Eastern, New Delhi.
4. Searle, S.R. (1982). Matrix Algebra Useful for Statistics, John Wiley, New York.

Paper VI

Estimation Theory

Unit I

Exponential family of distributions - Statistical decision problems – Loss functions – Risk function – Minimax decision. Point estimator – Amount of concentration, Mean squared error and variance - Sufficiency – Factorization theorem – Minimal sufficiency – Completeness – Ancillary statistic – Basu's theorem.

Unit II

Unbiased estimator – Estimand – Estimable function – Rao-Blackwell's theorem - uniformly minimum variance unbiased estimator – Lehmann - Scheffe's theorem - Fisher's information measure – Fisher's information matrix. Lower bounds to variance of unbiased estimators – Cramer - Rao lower bound, - Bhattacharya's lower bound – Chapman - Robbins lower bound.

Unit III

Methods of estimation – Method of moments - method of minimum χ^2 - method of modified minimum χ^2 - Likelihood function and its plotting – method of maximum likelihood – method of scoring and Newton - Raphson's method - Natural conjugate priors and Jeffreys non-informative prior – Bayes estimator under squared error loss function – Bayes risk.

Unit IV

Consistent and consistent asymptotically normal estimators. Asymptotic properties of moments, percentiles and maximum likelihood estimators - Consistent asymptotically non-normal estimators. Asymptotic relative efficiency.

Unit V

Interval estimation – confidence co-efficient and confidence interval – duality between acceptance region and confidence interval. Pivotal quantity method - large sample method - confidence belt - Chebyshev's inequality and their applications - Shortest length confidence interval. Construction of confidence intervals for population proportion (small and large samples) and difference between two population proportions (large samples) – confidence intervals for mean and variance of a normal population – confidence intervals for difference between means and ratio of variances of two normal populations.

Books for Study

1. Bansal, A.K. (2007). Bayesian Parameteric Inference, Narosa Publishing House, New Delhi.
2. Casella, G., and Berger, R.L. (2002). Statistical Inference, Second Edition, Thompson Learning, New York. (Reprint, 2007).
3. Mood, A.M., Graybill, F.A., and Boes, D.C. (1974). Introduction to Theory of Statistics, Third Edition, McGraw-Hill International Edition.
4. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
5. Rohatgi, V.K. and Saleh, A.K.Md.E. (2011). An Introduction to Probability and Statistics Second Edition, John Wiley & Sons, New York.

Books for Reference

1. Berger, J.O. (1985). Statistical Decision Theory and Bayesian Analysis, Second Edition, Springer Verlag, New York.
2. Goon, A.M., Gupta, M.K., and Dasgupta, B. (1989). An Outline of Statistical Theory, Vol. II, World Press, Kolkata.
3. Kale, B.K. (2005). A First Course in Parametric Inference, Second Edition, Narosa Publishing House, New Delhi. (Reprint, 2007).
4. Kale, B.K., and Muralidharan, K. (2015). Parametric Inference, Narosa Publishing House, New Delhi.
5. Keith, K. (2000). Mathematical Statistics, Chapman and Hall/CRC, New York.
6. Lehmann, E.L., and Casella, G. (1998). Theory of Point Estimation, Second Edition, Springer Verlag, New York. (Reprint, 2008).
7. Mukhopadhyay, P. (2002). Mathematical Statistics, Book and Allied Publishers, New Delhi.
8. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, Second Edition, Wiley Eastern Ltd., New Delhi.

Paper VII

Statistical Quality Control and Reliability

Unit I

Meaning and scope of statistical quality control - causes of quality variation - Control charts for variables and attributes - rational subgroups - construction and operation of $\bar{x}$, σ, R, np, p, c and u charts - operating characteristic curves of control charts. Process capability analysis using histogram, probability plotting and control chart - Process capability ratios- use and their interpretations.

Unit II

Specification limits and tolerance limits - Modified control charts - basic principles and design of cumulative-sum control charts – Concept of V - mask procedure – Tabular CUSUM charts. Moving-average and geometric moving-average control charts - sloping control chart.

Unit III

Acceptance sampling: Sampling inspection by attributes – single, double and multiple sampling plans – Rectifying Inspection. Measures of performance: OC, ASN, ATI and AOQ functions. Concepts of AQL, LTPD and IQL. Dodge – Romig and MIL-STD-105D tables. Sampling inspection by variables - known and unknown sigma variables sampling plan - merits and limitations of variables sampling plan - derivation of OC curve – determination of plan parameters.

Unit IV

Continuous sampling plans by attributes - CSP-1 and its modifications - concept of AOQL in CSPs - Multi-level continuous sampling plans - Operation of multi-level CSP of Lieberman and Solomon - Wald-Wolfowitz continuous sampling plans. Sequential Sampling Plans by attributes - OC and ASN functions.

Unit V

Concept of reliability, components and systems, coherent systems, reliability of coherent systems - Life distributions, reliability function, hazard function, hazard rate, failure rates, common life distribution - exponential, Weibull, gamma distributions - Estimation of parameters. IFR and DFR distributions - Reliability of system with independent components - Basic idea of maintainability - Censoring and life testing, series and parallel systems.

Books for Study

1. Duncan, A.J. (2003.). Quality Control and Industrial Statistics, Irwin - Illinois.
2. Grant, E.L., and Leavenworth, R.S. (2000). Statistical Quality Control, Seventh Edition, Tata McGraw Hill, New Delhi.
3. Montgomery, D.C. (2009). Introduction to Statistical Quality Control, Sixth Edition, Wiley India, New Delhi.
4. Zacks, S.(1992). Introduction to Reliability Analysis: Probability Models and Statistical Methods, Springer, New York.

Books for Reference

1. Barlow, E.B., and Proschan, F. (1981). Statistical theory of Reliability and Life Testing: Probability Models, Second Edition, Published by Holt, Rinehart & Winston, Inc.

2. Bowker, A.H., and Lieberman, G.J. (1982). Engineering Statistics, Second Edition, Prentice Hall, New Delhi,

3. Juran, J.M., and De Feo, J.A. (2010). Juran's Quality control Handbook – The Complete Guide to Performance Excellence, Sixth Edition, Tata McGraw-Hill, New Delhi.

4. Mahajan, M. (2002). Statistical Quality Control, (Third Edition), Dhanpat Rai and Co., Delhi.

5. Schilling, E. G., and Nuebauer, D.V. (2009). Acceptance Sampling in Quality Control Second Edition, CRC Press, New York.

6. Wetherill, G.B. (1977). Sampling Inspection and Quality Control, Second Edition, Chapman and Hall, London.

Elective I

Programming in C++

Unit I

Principles of Object Oriented Programming –Software Crisis – Software Evolution – Procedure Oriented Programming – Object Oriented Programming paradigm – Basic concepts and benefits of OOP – Structure of C++ - Manipulators.

Unit II

Functions in C++ : Functions prototyping – Call by Reference – Return by Reference – In – line function – Default, Const Arguments –Functions Overloading – Friend and Virtual Functions – Classes and Objects - Member functions – Nesting of Member functions – Private member functions – Memory allocation for objects – Static data members – Static member function – Returning Object – Const Member Function – Pointers to members.

Unit III

Constructors: Parameterized Constructors – Multiple Constructors in C Classes – Constructors with Default Arguments – Dynamic – Initialization of Objects – Copy and Dynamic Constructors – Destructors - Operator Overloading – Unary and Binary Operators – Overloading Binary Operators using Friend Functions.

Unit IV

Composition and Inheritance: Meaning - Protected class members - Overriding and dominating inheritance – Private Access Versus Protected Access - Virtual Functions and Polymorphism - Virtual destructors – Abstract base classes.

Unit V

Templates and Iterators: Function, class and subclass templates – Container classes – Passing template classes to template parameters – Iterator classes.

Books for Study

1. Balagurusamy, E. (2001). Object oriented Programming with C^{++}, Second Edition, Tata - McGraw Hill Publishing Company Limited, New Delhi.

Books for Reference

1. Hubbard, J. R. (1996). Programming with C^{++}. Second Edition, Schuam's Outline Series, McGraw – Hill, New York.
2. Lafore, R. (1995): Object Oriented Programming with C++. Tata McGraw Hill Publishing Company Limited.
3. Stroup, B. (1991): The C++ Programming Language, Addison Wesley.

Elective I

Official Statistics

Unit I

Introduction to Indian and International statistical systems - Role, function and activities of Central and State Statistical Organizations - Organization of large scale sample surveys - Role of National Sample Survey Organization - General and special data dissemination systems.

Unit II

Population growth in developed and developing countries - Evaluation of performance of family welfare programmes - Projections of labour force and manpower - Scope and content of population census of India.

Unit III

System of collection of Agricultural Statistics - Crop forecasting and estimation - Productivity, fragmentation of holdings - Support prices - Buffer stocks - Impact of irrigation projects**.**

Unit IV

Statistics related to industries - Foreign trade - Balance of payment - Cost of living – Inflation - Educational and other social statistics.

Unit V

Indian official statistics : Present official statistical system in India - Methods of collection of official statistics, their reliability and limitations - Principal publications containing data on the topics such as population, agriculture, industry, trade, prices, labour and employment, transport and communications - Banking and finance - Various official agencies responsible for data collection and their main functions.

Books for Reference

1. Basic Statistics Relating to the Indian Economy (CSO) 1990.
2. Family Welfare Yearbook. Annual Publication of D/o Family Welfare.
3. Guide to Official Statistics (CSO) 1999.
4. Monthly Statistics of Foreign Trade in India, DGCIS, Calcutta and other Government Publications.
5. Panse, V. G., Estimation of Crop Yields (FAO).
6. Principles and accommodation of National Population Censuses, UNESCO.
7. Statistical System in India (CSO) 1995.

Elective I

Data Mining

Unit I

Introduction: Data mining- Kinds of data – Data mining Functionalities - Classification of Data mining Systems - Major Issues on Data mining - Introduction to OLAP - OLAP technology for Data Mining - Data warehousing - Data warehousing to Data mining - Optimizing Data for mining - Data preprocessing.

Unit II

Data Mining Primitives: Data mining Query language - Association Rules in large - Data mining - KDD Process - Fuzzy sets and logic - Classification and Prediction**:** Information retrieval - Dimensional Modeling of Data - Pattern Matching - Estimation Error- EM and MLE.

Unit III

Models based on Summarization: Bayes Theorem - Chi square Statistics Regression - Decision Tree - Neural Networks - Genetic Algorithms - Cluster Analysis – Outlier - Cluster vs Classification - Clustering Issues - Impact of Outliers on clustering- Clustering problems - Clustering Approaches.

Unit IV

Clustering Algorithms: Hierarchical algorithm – Single Linkage - MST Single Linkage - Complete Linkage - Average Linkage. Dendrogram - Partition Algorithm – MST - Squared Error – *K* - Means - Nearest Neighbor – PAM – BEA – GA - Categorical algorithm - Large Database.

Unit V

Web Mining: Introduction - Webdata - Web Knowledge Mining Taxonomy - Web Content mining - Web Usage Mining Research - Ontology based web mining Research - Web mining Applications.

Books for Reference

1. Berry, J.A., and Linoff, G.S. (2011). Data Mining Techniques, Third Edition, John Wiley and Sons, New York.
2. Chattamvelli, R. (2009). Data mining Methods, Alpha Science International.
3. Dunham, M.H. (2006). Data Mining: Introductory and Advanced Topics, Pearson Education India.
4. Gorunescu, F. (2010). Data mining Concepts, Models and Techniques, Springer.
5. Han, J., and Kamber, M. (2001). Data mining Concepts and Techniques, Seventh Edition, Morgan Kaufmann Publications.
6. Hand, D., Mannila, H., and Smyth, P. (2001). Principles of Data mining, MIT press.
7. Larose, D.T. (2005). Discovering Knowledge in Data: An Introduction to Data Mining. John Wiley and Sons, Canada.
8. Pujari, A.K. (2001). Data Mining Techniques, Universities Press.
9. Sivanandam, S.N., and Sumathi, S. (2006). Data Mining Concepts, Tasks and Techniques, Springer.

Elective I

Actuarial Statistics

Unit I

Mortality: Level, trend and differentials in mortality - forces of mortality - Gombertz and Makeham laws of mortality- Complete and abridged life tables-construction, interpretation - applications -stationary funds.

Unit II

Annuities: Pure endowments - Annuities – Accumulations – Assurances - Varying annuities and assurances - Continuous annuities - family income benefits.

Unit III

Policy Values: Nature of reserve - prospective and retrospective reserves - fractional premiums and fractional durations - modified reserves - Continuous reserves - Surrender values and paid up policies - Industrial assurance - Children's deferred assurances - Joint life and last survivorship.

Unit IV

Contingent Functions: Contingent probabilities - Contingent assurances - reversionary annuities - multiple-decrement table - forces of decrement - construction of multiple decrement tables.

Unit V

Pension Funds: Capital sums on retirement and death - widow's pensions - Sickness benefits - Benefits dependent on marriage.

Books for Reference

1. Barcley G.W. (1970). Techniques of Population Analysis. John Wiley, New York.
2. Borowiak, D.S., and A. F. Shapiro. (2013). Financial and Actuarial Statistics: An Introduction, Second Edition. CRC Press.
3. Donald, D.W.A. (1970). Compound interest and annuities, Second Edition, The Institute of Actuaries and the Faculty of Actuaries at the University Press.
4. Elandt-Johnson, R.C., and Johnson, N. L. (1999). Survival Models and Data Analysis, John Wiley and Sons, New York.
5. King, G. Institute of Actuaries Textbook, Part II, Second Edition, Institute of Actuaries (Great Britain).
6. Spurgeon, E.T. (2011), Life Contingencies, Third Edition, Cambridge University Press.

Elective II

Operations Research

Unit I

Operations Research: Meaning, Objectives and Scope. Phases of Operations Research Linear Programming Problem (LPP): General Formulation - Illustrations – Methods of Solving LPP - Graphical and Simplex Methods – Concept of Cycling and Degeneracy. Problem of Duality - Dual Simplex Method – Simple Problems – Game Theory: Zero-sum games, Maximin and Minimax Criteria – Minimax and Saddle Point Theorems – Dominance Property.

Unit II

Transportation Problems (TP): Mathematical Formulation – Illustrations - Relationship Between TP and LPP – Methods for finding Basic Feasible Solutions – Optimality – Transportation Algorithm – Concept of Degeneracy – Unbalanced Transportation Problem. Assignment Problem – Formulation - Illustrations – Method of solving an Assignment Problem.

Unit III

Queueing Theory: Queueing models – Queueing system – Queueing problem - Definition of transient and steady-states - Kendall's notations and classification of queuing models - Distributions in queuing systems - Solution of queuing models: Model I: (M/M/1:∞/FCFS) - Birth and Death Model. Model-II - General Erlangian queueing model (Birth-Death Process). Model-III: (M/M/1: N/FCFS) and Model IV: (M/M/S/∞/FCFS) - Steady-state solutions of Markovian queuing models of M/M/1, M/M/C and M/G/1 with limited waiting spaces.

Unit IV

Theory of Inventory: Meaning of Inventory – Economic Order Quantity - Deterministic and Probabilistic Inventory Models - Models with and without shortages – Concept of ABC Analysis.

Unit V

Replacement Problems: Replacement of deteriorating items – Complete replacement of items – Individual and Group Replacement Policies. Network Analysis: Concept – Network Diagram – Fulkerson's Rule. Project Management and Scheduling. PERT and CPM: Meaning and Description – Determination of Critical Path.

Books for Study

1. Gass, S. I. (1985). Linear Programming, Methods and Applications. Courier Dover Publications. (Reprint 2003)
2. Swarup, K., Mohan, M., and Gupta P.K. (2001). Operations Research, Sultan Chand and Sons, New Delhi.
3. Taha, H.A (2011). Operations Research: An Introduction, Ninth Edition, Prentice Hall Publishing Company.

Books for Reference

1. Gupta, P.K., and Man Mohan. (1979). Operations Research: Linear Programming and Theory of Games, Third Edition, Sultan Chand and Sons, New Delhi.
2. Hadley, G (1963): Linear Programming. Addison Wesley Publishing Company.

3. Hillier, F.S., and Lieberman, G.J. (2005). Introduction to Operations Research, Ninth Edition, McGraw – Hill Publishing Company.
4. Sharma, J.K. (2013). Operations Research: Problems and Solutions, Fifth Edition, Macmillan India Limited.
5. Sharma, S. D. (2010). Operations Research, Kedar Nath, Ram Nath and Co, Meerut.

Elective II

Simulation and Statistical Modeling

Unit I

Simulation: Introduction, appropriate and not appropriate, advantages and disadvantages, application areas. System and system environment, components of system, type of systems, model of a system, types of models and steps in simulation study.

Unit II

Statistical Models in Simulation: Useful statistical model, discrete distribution, continuous distribution, empirical distribution. Poisson distribution, Uniform distribution, Exponential distribution, Triangular distribution, Gamma distribution.

Unit III

Random Number Generation: Properties of random numbers, generation of true and pseudo random numbers, techniques for generating random numbers, hypothesis testing, various tests for uniformity (Kolmogorov-Smirnov and chi-Square) and independence (runs, autocorrelation). Random Variate Generation: Introduction, different techniques to generate random variate - inverse and direct transform techniques, convolution method and acceptance rejection techniques.

Unit IV

Input Modeling: Introduction, steps to build a useful model of input data, data collection, identifying the distribution with data, parameter estimation, suggested estimators, goodness of fit tests, selection input model without data, covariance and correlation, time series input models.

Unit V

Verification and Validation of Simulation Models: Model Building - Verification and Validation - Verification of Simulation models - Calibration and Validation of models: Face Validity - Validation of model Assumptions - Validations Input-Output Transformations - Input-Output Validation using Historical Input Data - Input-Output Validation using a Turing Test.

Books for Reference

1. Banks J., Carson J. S., Nelson B. L., and Nicol D. M. (2001). Discrete Event System Simulation, Third Edition, Pearson Education.
2. Deo, N. (1983). System Simulation with Digital Computer, Prentice Hall of India (Digitized 2007).
3. Gardon, G. (1992). System Simulation, Second Edition, Prentice Hall of India.
4. Law, A.M. (2007). Simulation Modeling and Analysis, Fourth Edition, McGraw-Hill Education.

Elective II

Biostatistics

(*Note: This paper will be taught focusing mainly on the applications of the statistical concepts and methods in biological studies*)

Unit I

Introduction Definition/Phases of Clinical Trials; Study Design: Cohort, case-control and observational studies; Terminology of prospective, retrospective; treatment allocation, randomization and stratification, quality control, biases, sample size requirements, patient consent

Hypotheses / Aims: superiority, non-inferiority, equivalence primary, secondary; various types of clinical data (continuous, categorical, count, and time-to-event outcome data); Basic biological concepts in genetics, Basic concept of Bioassays and different Types of biological assays.

Unit II

Disease-Exposure Association: Risk, odds, odds ratio, relative risk, standard errors; Contingency Tables: Association (Chi-square test), Confounding (Mantel-Haenszel), Interactions (Test of homogeneity); Probability Diagnostic Testing and Screening.

Unit III

Descriptive Statistics; Estimation for Means; Estimation for Proportions; One Sample Hypothesis Test – Means ; One Sample Hypothesis Test – Proportions; Two Sample Hypothesis Test; Non-Parametric Hypothesis Testing; One Way ANOVA.

Unit IV

Introduction to Linear Regression and Correlation; Logistic Regression: estimation: Logistic regression for case-control studies, estimation and interpretation of logistic parameters.

Unit V

Introduction to Survival: Concepts of time, Censoring-different types of censoring- right and left, Survival function- Kaplan-Meier (K-M) estimator; Nonparametric Methods for Comparing Survival Distributions - log rank test, Peto's test, Gehan test, Mantel-Haenzel test. Cox Proportional Hazard regression, parametric survival models – Basic life time distributions - Exponential, Weibull, Gamma Log-Normaland Log- logistic.

Reference

1. Fundamentals of Biostatistics : Bernard Rosner Recommended 6th /7th Edition
2. Friedman, Furberg & DeMets: Fundamentals of Clinical Trials, 3rd Edition, 1996. Mosby-Year Book, Inc.
3. Rossi R.J. (2010).Applied Biostatistics for Health Sciences, Wiley.
4. Cox, P.R. (1978): Demography (Fifth Edition). Cambridge University Press.
5. David G. K., and Klein, M. (2008). Survival analysis - A Self-Learning Text, Second edition, Springer.
6. Lee, E. T., and Wenyu, J. (2003). Statistical methods for Survival Data Analysis, Third Edition, John Wiley & Sons.

Supportive Paper

Descriptive Statistics

Unit I

Origin - Scope – Functions, limitations, uses and misuses of statistics - Classification and Tabulation of data - Diagrammatic and Graphical representation of data.

Unit II

Measures of Central tendency - Measures of Dispersion - Relative measures of dispersion - skewness and kurtosis - Lorenz curve.

Unit III

Elementary probability space - Sample space - discrete probability, independent events - Mathematical and Statistical probability - Axiomatic approach to probability - Addition and multiplication theorems - conditional probability – Bayes' theorem - Simple problems.

Unit IV

Random variables - Discrete and continuous random variables - Distribution function – probability mass function and probability density function of a random variable - Expectation of a random variable - evaluation of standard measures of location, dispersion, skewness and kurtosis.

Unit V

Simple linear correlation and regression - Scatter diagram - Karl Pearson's correlation coefficient and its properties - Spearman's correlation co-efficient. Regression equations - Fitting of regression equations - Regression coefficients and its properties.

Books for Study

1. Goon, A.M., Gupta, M.K. and Dasgupta, B. (2008). Fundamentals of Statistics, Vol. I, World Press Ltd, Calcutta.
2. Gupta, S.C. and V.K. Kapoor. (2000). Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi.
3. Hogg, R.V., McKean, J.W. and Craig, A.T. (2013). Introduction to Mathematical Statistics, (Seventh Edition), Pearson Education Ltd.
4. Spiegel, M.R., Schiller, J. and Srinivasan, R.A. (2012). Probability and Statistics, Schaum's Outline Series (Fourth Edition), McGraw- Hill Publishing Company, New Delhi.

Supportive Paper

Computer Oriented Statistical Methods

Unit I

Introduction to Computing - Computer Codes and Arithmetic Overview of BASIC - Sampling and Frequency Distribution - Measures of Central Tendency - Measures of Dispersion - Moments - Computation of Moments.

Unit II

Discrete Probability Distributions: Probability - Characteristics of Probability - Discrete Distributions - Binomial Distribution - Poisson Distribution - Hypergeometric Distribution – Properties and Numerical problems.

Unit III

Curve Fitting: Linear Regression - Least Squares Fit - Nonlinear Fit - Fitting a Polynomial Function.

Unit IV

Correlation : Coefficient of Correlation - Properties of Correlation Coefficient - Rank Correlation - Multiple Correlation - Partial Correlation.

Unit V

Tests of Significance: Small sample and large sample tests - t Test, F Test and χ^2 test.

Books for Study

1. Balagurusamy, E. (2000): Computer Oriented Statistical and Numerical Methods, Macmillan Publishers India Limited.
2. Enslein, K., Ralston, A., and Wilf, H.S. (1976): Statistical Methods for Digital Computers. John Wiley & Sons, New York.

Supportive Paper

Statistics for Economics

Unit I

Nature and scope of statistics - characteristics and limitation of statistics - statistical investigation - preparation of questionnaire - design of sampling - simple random, stratified and systematic sampling - collection of data - primary and secondary data.

Unit II

Processing and presentation of data - Classification of data - tabulation of data - Formation of frequency tables - Diagrammatic presentation of statistical data - bar diagrams - pie diagrams and pictograms - simple problems – Graphical presentation of statistical data - Histogram, frequency curves and Ogive curve- simple problems.

Unit III

Measures of central tendency - mean, median, mode - simple problems - measures of dispersion - range, mean deviation, quartile deviation and standard deviation - relative measures of dispersion - simple problems. Concept of Skewness and Kurtosis - Karl Pearson's and Bowley's coefficients of Skewness- moments- coefficients of Skewness and Kurtosis - simple problems.

Unit IV

Correlation: Scatter diagram - simple correlation, Rank correlation. Regression - simple regression lines (without proof) - Tetrochoric correlation, Phi coefficient and Kendall's co-efficient - simple problems.

Unit V

Time Series – Components of time series – Trend, Seasonal, cyclical, random variations – Methods of measuring trend and seasonal variations. Index Numbers – Meaning and uses. Cost of living index numbers – Construction of Consumer's price index numbers – Wholesale price index numbers.

Books for Reference

1. Agarwal, B. L. (2006). Basic Statistics, New Age International, New Delhi.
2. Goon, A. M., Gupta, M. K., and Dasgupta, B. (2008). Fundamentals of Statistics, Vol. I, World Press Ltd, Calcutta.
3. Gupta, S.C., and Kapoor, V. K. (2000). Fundamentals of Mathematical Statistics, Tenth Edition. Sultan Chand and Sons, New Delhi.
4. Gupta S. C., and Kapoor, V. K. (2014). Fundamentals of Applied Statistics, Fourth Edition, Sultan Chand and Sons, New Delhi.
5. Saxena, H.C. (1967). Elementary Statistics, Sultan Chand & Co., New Delhi.

Supportive Paper

Mathematical Economics

Unit I

Elasticity of Demand - Total, Average and Marginal Cost Curves - Relation between Average and marginal Cost Curves - Minimum Average cost-Cost function in Cubic Form - Total Average - Marginal Revenue Curves - Total Revenue - Conditions for Profit Maximization - Effects of Taxation and Subsidy on monopoly.

Unit II

Indifference Curve - Rate of Commodity substitution (RCS)-Maximization of Utility - Income and substitution Effects – Important Results from Slutsky Equation - Elasticity form of Slutsky Equation.

Unit III

Production Function - Constant Product Curves: Isoquants - Shape of Isoquants and Ridge Lines- Least Cost Combination (constrained Cost Maximisation) - Constrained Profit Maximization - Homogeneous Function - Cobb-Douglas production function - Elasticity of substitution- Elasticity of substitution of Linearly Homogeneous Function - C.E.S. Function.

Unit IV

Multiple Production by Monopolist - Discriminating monopoly -Duopoly - Consumer's Surplus - Producer's Surplus.

Unit V

Input-Output Analysis: Assumptions - Closed and open Input-Output model - coefficient Matrix and Open model - Leontief Model - Alternative Way for Inverting the Leontief Matrix - Interpretation of the Alternative Formulation - Coefficient Matrix and closed model - Consumption function - Dynamic Input-Output model - Possible Weaknesses and Limitations of Input-Output Analysis.

Books for Reference

1. Allen, R.G.D. (2008). Mathematics for Economists, ELBS series, London.
2. Daus, P.H., and Whyburn, W.M. (1962). Mathematics for Economists, Addison and Wesley, Amsterdam.
3. Draper, J., and Klingman, J. (1972). Mathematical Analysis: Business and Economic Applications, Harper – Row publishing company.
4. Henderson, J.M., and Quandt, R.E. (1967). Micro Economic theory, McGraw- Hill.
5. Mehta, B C., and Madnani, G.M.K.(1977). Mathematics for Economists (Third Edition), Sultan Chand, New Delhi.
6. Tintner, G. (1966). Mathematics and Statistics for Economists, Holt, Rinehart and Winston, Inc.

Supportive Paper

Basic Statistical Methods

Unit I

Definition of Statistics and its applications in various disciplines - Collection of Data - classification, Tabulation and Graphical representation of data - construction of univariate and Bivariate frequency distribution - Measures of central tendency - Measures of dispersion - coefficient of variation.

Unit II

Random experiment - sample space - events - mathematical and statistical definition of probability - conditional probability – Bayes' theorem - Random variables - Distribution functions - moments - Binomial distribution - Poisson distribution - Normal distribution and their properties.

Unit III

Scatter diagram - Karl Pearson's coefficient of correlation - concurrent deviation method - coefficient of determination - Spearman's Rank correlation -Linear regression–fitting of regression lines.

Unit IV

Tests of significance - hypotheses - two types oferrors - power function - critical region - level of significance - smallsample tests based on t and F distributions. Chi-square test of goodness of fit - contingency table -Test of independenceof factors - Large sample tests.

Unit V

Test of equality of several population means one way and two way analysis of variance - Non-parametric tests Sign, Run and Median tests - two sample rank test. Sampling and its uses, sampling methods- Simple random sampling, systematic and stratified.

Books for Study and References

1. Agarwal, B.L. (2013). Basic statistics. Anshan Publications.

2. Sharma, J.K. (2007). Business Statistics (Second Edition). Pearson Education, New Delhi.

3. Sokal, P.R. and Rohlf, F.J. (1969). Bio Statistics. W.H. Freeman and Co., San Francisco.

Supportive Paper

Statistics for Behavioral Sciences

Unit I

Nature and scope of statistics - characteristics and limitation of statistics - statistical investigation - preparation of questionnaire - design of sampling - simple random, stratified and systematic sampling - collection of data - primary and secondary data.

Unit II

Processing and presentation of data - Classification of data - tabulation of data - Formation of frequency tables - Diagrammatic presentation of statistical data - bar diagrams - pie diagrams and pictograms - simple problems – Graphical presentation of statistical data - Histogram, frequency curves and Ogive curve- simple problems.

Unit III

Measures of central tendency - mean, median, mode - simple problems - measures of dispersion - range, mean deviation, quartile deviation and standard deviation - relative measures of dispersion - simple problems.

Unit IV

Concept of Skewness and Kurtosis - Karl Pearson's andBowley's coefficients of Skewness- moments- coefficients of Skewness and Kurtosis - simple problems.

Unit V

Correlation: Scatter diagram - simple correlation, Rank correlation. Regression - simple regression lines (without proof) - Tetrochoric correlation, Phi coefficient and Kendall's co-efficient - simple problems.

Books for Study and Reference

1. Camphell, R.C. (1989). Statistics for Biologists, Cambridge University Press, London.
2. Garret, H. E., and Woodworth, R. S. (2006). Statistics in Psychology and Education. Cosmo Publications, New Delhi.
3. Goon, A. M., Gupta, M. K., and Dasgupta, B. (2008). Fundamentals of Statistics, Volume-I, World Press Ltd, Calcutta.
4. Gupta, S. C., and Kapoor, V. K. (2000). Fundamentals of Mathematical Statistics, Tenth Edition, Sultan Chand and Sons, New Delhi.
5. Saxena, H. C. (1967). Elementary Statistics, Sultan Chand & Co., New Delhi.
6. Tate, M. W. (1964). Statistics in Education. Macmillan Co., New York.

Supportive Paper

Probability and Statistics for Scientists

Unit I

Sample spaces – events – Probability axioms – Conditional Probability – Independent events – Baye's formula - Random Variables - Distribution functions – Marginal distributions, Conditional distribution – Stochastic Independence. Expectation – Conditional expectation and Conditional Variance. Moment generating functions – Cumulant generating functions.

Unit II

Probabilty distributions – Binomial, Poisson, geometric, uniform, exponential, normal, gamma, beta (generating function, Mean, variance and Simple problems). Sampling distributions - *t*, *f*, Chi-square distributions- properties.

Unit III

Estimation: Point estimation – Characteristics of estimation – Interval estimation – Interval estimates of Mean, Standard deviation, proportion, difference in means and ratios of standard deviations.

Unit IV

Test for means, Variances & attributes using the above distributions large sample tests – tests for means, variances and proportions. Analysis of Variance: One way and two way classifications – Complete Randomized blocks – Randomized Block Design and Latin Square Design (Only Problems).

Unit V

Statistical quality control – Statistical basis for control charts – Control limits – Control Charts for variablesr and attributes – mean chart, range chart, standard deviation chart - charts for defectives, defects – *p*, *np*, *c* charts.

Books for Study and Reference

1. Gupta, S. C., and Kapoor, V. K. (1977). Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi.
2. Montgomery, D.C. (2009). Introduction to Statistical Quality Control, Sixth Edition, Wiley India, New Delhi.
3. Montgomery, D.C., and Runger, G. C. (2010), Applied Statistics and Probability for Engineers, Fifth Edition, John Wiley & Sons, New York.

Supportive Paper

Statistics for Researchers

Unit I

Definition of Statistics and its applications in various disciplines - Collection of Data - Classification, Tabulation and graphical representation of data- Construction of univariate and bivariate frequency distribution-measures of central tendency-measures of dispersion coefficient of variation.

Unit II

Random experiment-sample space-events-mathematical and statistical definition of probability-conditional probability - Baye's theorem - random variable - distribution function - moments - Binomial distribution - Poisson distribution - normal distribution and their properties

Unit III

Scatter diagram - Karl Pearson's coefficient of correlation - concurrent deviation method coefficient of determination - Spearman's Rank correlation - Linear regression - regression lines.

Unit IV

Tests of significance - types of hypotheses - two types of errors - critical region - level of significance, small sample tests based on *t*, *F* distribution, Chi - square test of goodness of fit, contingency table - test of independence of factors - Large sample tests.

Unit V

Test of equality of several population means, one way and two way analysis of variance. Non-parametric tests - sign, run and median tests - two sample rank test - sampling and its uses, sampling methods - unrestricted Random sampling (SRS) - Restricted Sampling (Stratified and Systematic).

Books for Study and Reference

1. Agarwal (1980). Basic Statistics, Wiley Eastern.
2. Goon,A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Volume-I, World Press Ltd, Calcutta.
3. Gupta, S. C., and Kapoor, V. K. (2000). Fundamentals of Mathematical Statistics, Tenth Edition, Sultan Chand and Sons, New Delhi.
4. Sokal, P. R., and Rohlf, F. J. (1969). Bio Statistics, W.H. Freedom & Co, San Francisco.
5. Snedecor, G. W., and Cochran, W. G. (1967). Statistical Methods, Oxford-IBH, Pvt Co.

Statistics Practical I

Exercise under Distribution Theory

1. Fitting of Binomial distribution.
2. Fitting of Poisson distribution.
3. Fitting of normal distribution by area and ordinate methods.

Exercise under Sampling Theory

1. Estimation of population total, mean and variance under simple random sampling.
2. Estimation of population total, mean and variance under stratified random sampling.
3. Estimation of population total, mean and variance under systematic sampling.
4. Estimation of population total, mean and variance under single - stage and two - stage cluster Sampling.
5. Ratio and regression estimates.
6. Estimation of population total, mean and variance under double sampling methods.

Statistics Practical II

Exercise under Statistical Inference

1. Estimation of parameters under normal and exponential distributions by the methods of moments, maximum likelihood and minimum chi - square.
2. Estimation of confidence intervals for the mean, standard deviation, variance, difference of two means, standard deviations, ratio of variances based on normal, student's *t*, Chi-square and *F* distributions.

Exercise under Statistical Quality Control

1. Construction of control charts for mean, range and standard deviation.
2. Construction of control charts for fraction defective, number of defectives, number of defects and average number of defects per unit (*p*, *np*, *c* and *u* charts).
3. Construction of tabular CUSUM, moving - average and geometric moving - average control charts.
4. Construction of OC, ASN, ATI and AOQ curves of single and double sampling plans.
5. Construction of OC and ASN curves of sequential sampling plans.
6. Estimation of reliability function by the method of maximum likelihood and the estimation of failure rates for the life time distributions Exponential, gamma and Weibull distributions.

Paper VIII

Hypothesis Testing

Unit I

Testing of hypotheses: simple and composite hypotheses, two types of errors, level of significance, randomized and non - randomized tests, power and size of a test. Most powerful test - Neyman-Pearson lemma. Monotone likelihood ratio property - uniformly most powerful tests. Applications to standard statistical distributions.

Unit II

Generalization of Nyman-Pearson fundamental lemma (statement only). Unbiased tests - Construction of uniformly most powerful unbiased tests for one-parameter and multi - parameter exponential families-applications to standard statistical distribution-similar regions. Locally most powerful (LMP) test - LMP unbiased test.

Unit III

Invariance - maximal invariant statistic - invariant test. Likelihood ratio (LR) test-asymptotic distribution of LR test statistic-consistency of LR test - Construction of LR tests for standard statistical distributions. Analysis of variance (one - way). Bartlett's test for homogeneity of variances.

Unit IV

U statistic and its property as an estimator of its expected value. Tests for goodness of fit - Chisquare and Kolmogorov – Smirnov tests. Test for randomness. Wilcoxon's signed - rank test. Kolmogorov - Smirvon two sample test. Mann - Whitney *U* test. Kruskal - Wallis test – Median Test – Friedman's Test.

Unit V

Introduction to sequential procedures - Stopping times - Wald's equation. SPRT: Termination property, approximation to stopping bounds and applications to standards distributions. Statement of Wald's fundamental identity. OC and ASN functions and their plotting.

Books for Study and Reference

1. Casella, G. and Berger, R.L. (2002). Statistical Inference (Second Edition). Thompson Learning, New York. (Reprint, 2007).
2. Conover, W. J. (1999). Practical Nonparametric Statistics (Third Edition). John Wiley & Sons, New York. (Reprint, 2007).
3. Gibbons, J. D., and Chakraborti, S. (2010). Nonparametric Statistical Inference (Fifth Edition). Taylor & Francis, New York.
4. Goon, A.M., Gupta, M. K., and Dasgupta, B. (1989). An Outline of Statistical Theory, Vol. II, World Press, Kolkata.
5. Kale, B. K. (2005). A First Course in Parametric Inference (Second Edition). Narosa Publishing House, New Delhi. (Reprint, 2007).
6. Lehmann, E. L. and Romano, J.P.(2005). Testing Statistical Hypotheses (Third Edition), Springer Verlag, New York. (Reprint, 2009).
7. Rao, C.R. (1973). Linear Statistical Inference and Its Applications (Second Edition), Wiley Eastern Ltd., New Delhi.

8. Rohatgi, V.K. and Saleh, A.K.Md.E.(2001). An Introduction to Probability and Statistics (Second Edition), John Wiley & Sons, New York. (Reprint, 2009).
9. Rajagopalan, M. and Dhanavanthan, P. (2012). Statistical Inference. PHI Learning Pvt. Ltd., New Delhi.
10. Wald, A. (1982). Sequential Analysis, John Wiley & Sons, New York.

Paper IX

Multivariate Analysis

Unit I

Singular and non-singular multivariate normal distributions and their properties - Marginal and conditional distributions - Characteristic function and moments - Distribution of linear combinations of multivariate normal vector - Determination of mean and variance - covariance matrix of multivariate normal distribution.

Unit II

Random Sampling from multivariate normal distribution - Maximum likelihood estimators of the parameters of multivariate normal distribution - distribution of sample mean vector - Necessary and sufficient conditions for a quadratic form to be distributed with a chi - square distribution - Inference concerning the sample mean vector when covariance matrix is known.

Unit III

Generalized T^2 statistic and its distribution - Hotelling's T^2 statistic, properties, applications and its distribution - Two sample problems with unequal covariance matrices likelihood ratio criterion and its applications - Mahalanobis D^2 statistic and its distribution - Relationship between T^2 and D^2 statistics – Behrens – Fisher problem.

Unit IV

Wishart distribution - Sampling distribution of sample covariance matrix - Properties of Wishart distribution - Wilk's criterion - Generalized variance (Concept only) - Sampling distribution of simple sample correlation coefficient - Sampling distribution of partial and multiple correlation coefficients in null case (without derivation) - Tests concerning simple, partial and multiple correlation coefficients - Discriminant function (concept only) - Fisher's discriminant function.

Unit V

Problem of classification - Two populations and k populations - Principal components and their determination - Factor analysis – estimation of factor loadings - Canonical variables and canonical correlations - Derivation of canonical correlation coefficients.

Books for Study and Reference

1. Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis (Third Edition). Wiley – Inter science, New York.
2. Johnson, R.A. and D.W. Wichern. (2013). Applied Multivariate Statistical Analysis (Sixth Edition), Pearson New International Edition.
3. Kendall, M.G., Stuart, A. and Ord, K.J. (1973). The Advanced Theory of Statistics. (Fourth Edition), Vol. 2, Charles Griffin company Ltd.
4. Kotz, S., Balakrishnan, N. and Johnson, N.L. (2000). Continuous Multivariate Distribution Models and Applications (Second Edition). Volume 1, Wiley - Inter science, New York.
5. Mardia, K.V., Kent, J. T and Bibby, J. M. (1979). Multivariate Analysis. Academic Press, New York.
6. Morrison, D.F. (2004). Multivariate Statistical Methods (Fourth Edition). Duxbury Press, New York.

7. Rao, C.R. (2001). Linear Statistical Inference and its Applications (Second Edition). Wiley-Inter Science, New York.

Paper X

Demographic Methods

Unit I

Demography: Meaning, scope and its development, demographic data and their sources - Current status - Chandrashekar - Deming index - Adjustment of age data – Population size and growth in India - Trends and differentials in world population. – Health Surveys and use of hospital statistics – Population transition theory.

Unit II

Mortality - Basic measurements - Crude, specific, standardized death rates - Life table - construction, use and interpretation - force of mortality - abridged life tables.

Unit III

Fertility - Basic measurements - Gross and Net Reproduction rate - Cohort fertility analysis - Fertility models - Population regulation programs in India - Demographic transition theory.

Unit IV

Special distribution of population - basic concepts - measurements and models of migration - concept of international migration - Urban development, components of urban and metropolitan growth - Urbanization in developed and developing countries - Stable and quasi populations- Intrinsic growth rate.

Unit V

Components of population growth and change – Models of population growth and their filling to population data - Methods of projection - Logistic equation and fitting - component method of projection - stable population theory – Decennial population census in India – Nuptiality and its measurements.

Books for Study and Reference

1. Benjamin, B. (1975). Demographic Analysis. George Allen and Unwin Limited.
2. Bogue, D. J. (1969). Principles of Demography, Wiley, New York.
3. Cox, P.R. (1978). Demography (Fifth Edition). Cambridge University Press.
4. David G. K., and Klein, M. (2008). Survival analysis - A Self-Learning Text, Second edition, Springer.
5. Gibbs, J.P. (2012). Urban Research Methods. Literary Licensing, LLC.
6. Keyfitz, N. and Caswell, H. (2006). Applied Mathematical Demography. Springer lag, New York.
7. Kumar, R. (1986). Technical Demography. John Wiley & Sons, Canada.
8. Lee, E. T., and Wenyu, J. (2003). Statistical methods for Survival Data Analysis, Third Edition, John Wiley & Sons.
9. Misra, B.D. (1982). An Introduction to the Study of Population, South East Asia Publishers, New Delhi.
10. Spiegelman, M. (1969). Introduction to Demographic Analysis. Harvard University Press.

Paper XI

Econometrics

Unit I

Nature and Scope of Econometrics - Single Equation Regression Models – Generalized Linear Model (GLM) and its existence - Ordinary least square (OLS) Method of Estimation and Prediction. Precision of OLS Estimates - Properties of Estimates under Normality Assumption - Dummy Variables: Nature and Use – Caution - Generalized least square (GLS) Method of Estimation and Prediction- Two variables only.

Unit II

Homoscedasticity and Heteroscedasticity: Nature – OLS Estimation and Its Consequences – Detection: Informal and Formal Methods ((Park, Goldfeld and Quandt test)) - Remedial Measures – Method of GLS. Concept of Multicollinearity: Effects, Detection and Remedial Measures - Problem of Aggregation.

Unit III

Concept of Autocorrelation: OLS Estimation – BLUE - Consequences of Using OLS – Tests for Detection – Remedial Measures – GLS. Ridge Regression - Autoregressive and Distributed Lag Models: Estimation of Models – Method of Instrumental Variables – Autocorrelation in Autoregressive Models – Durbin *h* test.

Unit IV

Simultaneous Equation Model: Nature and Illustrations - Simultaneous Equation Bias -Problem of Identification – Under and Over Identification - Rules for Identification: Order and Rank Conditions of Identifiability. Test of Simultaneity – Test for Exogeneity.

Unit V

Simultaneous Equation Model: Approaches to Estimation Recursive Models and OLS Estimation of an Identified Equation: Method of Indirect Least Squares. Estimation of an over-identified Equation: Method of Two-stage and Three-stage Least Squares Estimation – Method of Maximum Likelihood Estimation. Monte Carlo studies and simulation for Model specification.

Books for Study and Reference

1. Castle, J. and Shephard, N. (2009). The Methodology and Practice of Econometrics. OUP Oxford Publications.
2. Gujarati, D. N. (2008). Basic Econometrics, Fifth Edition, McGraw Hill Publisher, New York.
3. Goldberger, A.S. (1964): Econometrics theory. John Wiley & Sons, New Delhi.
4. Johnston, J., and J. DiNardo,.(1997). Econometric Methods, McGraw-Hill.
5. Kelejion, H.H. and Oates, W.E. (1988). Introduction to Econometrics: Principles and Applications. Harper and Row Publishers Inc., New York.
6. Khotsoyiannis, A. (1977). Theory of Econometrics. Second Edition, Macmillan.
7. Maddala, G.S. and Lagari, K. (2009). Introduction to Econometrics. John Wiley & Sons, New York.
8. Madnani, G.M.K. (2008). Introduction to Econometrics: Principles and Applications. Oxford and IBH Publishing.

9. Wooldridge, J. (2012). Introduction Econometrics: A Modern Approach. Cengage Learning.

Paper XII

Linear Models and Design of Experiments

Unit I

Linear models – assumptions on error components – Fixed, Random and mixed effects models, models with full rank and less than full rank - least square and maximum likelihood estimators of the parameters and their properties – Gauss - Markov theorem - testing linear hypotheses.

Unit II

Analysis of variance for one - way, two - way classification with one and more than one (equal) observations per cell with interaction - Multiple comparisons: Fisher's least significance difference (L.S.D.) test and Duncan's Multiple Range test (DMRT) - Analysis of covariance (ANCOVA) - description of the method in the case of one and two concomitant variables - analysis of mixed plot data, three way concomitant.

Unit III

Fundamental principles of design of experiments - Randomization, Replication and Local control - Completely randomized design(CRD) - Randomized block design(RBD) - Latin square design(LSD) and their analyses - Missing plot technique for RBD and LSD - more than one observation per cell in RBD - Graeco - LSD - ANACOVA technique in CRD, RBD and LSD - Transformations.

Unit IV

Factorial experiments - 2^4 and 3^3 experiments and their analysis - complete and partial confounding, their construction - Analysis in 2^4 and 3^3 experiments - Fractional replication in 2^4 and 3^3 experiments - Construction and their analysis - concept of asymmetrical factorial experiments - Split-plot and Strip-plot designs.

Unit V

Incomplete block design - Balanced incomplete block design and partially balanced incomplete block design with two associate classes-parametric relation and analysis - Youden square design-concept and analysis - Concept of Lattice design - Analysis of non-orthogonal data.

Books for Study and Reference

1. Cochran, W. G and Cox, G. M. (1957). Experimental Design. John Wiley &sons, New York.
2. Das, M. N. and Giri, N. S. (1986). Design and Analysis of Experiments (2nd Edition). Wiley Eastern Ltd., New Delhi.
3. Dey, A. (2010). Incomplete Block Design. World Scientific Publishing Company.
4. Fisher, R. A. (1953). Design and Analysis of Experiments. Oliver and Boyd, London.
5. Giri, N.C. (1986). Analysis of Variance. South Asian Publisher, New Delhi.
6. John, P.W.M (1998). Statistical Design and Analysis Experiments.Macmillan Company, New York.
7. Joshi, D.D (1987). Linear Estimation and Design of Experiments, New Age International (P) Ltd. New Delhi.
8. Kempthorne, O. (1976). Design and Analysis of Experiments. John Wiley & Sons, New York.

9. Montgomery, D.C. (2012). Design and analysis of Experiments. John Wiley & Sons, New Delhi.
10. Panneerselvam, R. (2012). Design and Analysis of Experiments, Prentice Hall.
11. Searle, S.R. (2012). Linear Models. John Wiley & Sons, Inc., New York.

Paper XIII

Stochastic Processes

Unit I

Introduction to Stochastic Processes Classification of Stochastic Processes, Markov Processes Markov Chain Countable State Markov Chain. Transition Probabilities, Transition Probability Matrix. Chapman - Kolmogorov's Equations, Calculation of *n* - step Transition Probability and its limit.

Unit II

Classification of States, Recurrent and Transient States -Transient Markov Chain, Random Walk and Gambler's Ruin Problem. Continuous Time Markov Process: Poisson Processes, Birth and Death Processes, Kolmogorov's Differential Equations, Applications, Properties.

Unit III

Branching Processes –Galton –Watson Branching Process -Properties of Generating Functions – Extinction Probabilities –Distribution of Total Number of Progeny. Concept of Weiner Process.

Unit IV

Renewal Processes – Renewal Process in Discrete and Continuous Time – Renewal Interval – Renewal Function and Renewal Density –Renewal Equation – Renewal theorems: Elementary Renewal Theorem. Probability Generating Function of Renewal Processes.

Unit V

Statationary Processes Application to Time Series. Autocovariance and Autocorrelation functions and their properties. Moving Average, Autoregressive, Autoregressive Moving Average, Autoregressive Integrated Moving Average Processes. Basic ideas of residual analysis, diagnostic checking, forecasting.

Books for Study and Reference

1. Bhat, B. R. (2000). Stochastic Models: Analysis and Applications, New Age International (P) Ltd.
2. Bhat, U. N., and Miller, G. K. (2002). Elements of Applied Stochastic Processes, Third Edition, Wiley -Interscience.
3. Box, G.E.P., and Jenkins, G.M., (1976). Time Series Analysis - Forecasting and Control. Holden-Day San Francisco.
4. Karlin,S. and Taylor,H.M. (1975). A First Course in Stochastic Process, Second Edition, Academic Press.
5. Medhi, J. (2002). Stochastic Processes, Second Edition, New Age International (P) Ltd.
6. Parzen, E. (1962). Stochastic Processes, Holland-Day

Elective III

Categorical Data Analysis

Unit I

Models for Binary Response Variables, Log Linear Models, Fitting Log linear and Logic Models- Building and applying Log Linear Models, Log- Linear - Logit Models for Ordinal Variables.

Unit II

Multinomial Reponse Models - Models for Matched Pairs- Analyzing Repeated Categorical Response Data - Asymptotic Theory for Parametric Models - Estimation Theory for Parametric Models.

Unit III

Classical treatments of 2 and 3-way contingency tables, measures of association and nonparametric methods - Generalized linear models - Logistic regression for binary - multinomial and ordinal data – Log - linear models - Poisson regression- Modeling repeated measurements- generalized estimating equations.

Unit IV

Introduction to contingency tables: 2×2and $r \times c$ tables - tests for independence and homogeneity of proportions - Fishers exact test - Odds ratio and Logit, other measures of association - Introduction to 3 - way tables – full independence and conditional independence - collapsing and Simpsons paradox.

Unit V

Polytomous logit models for ordinal and nominal response- Log-linear models (and graphical models) for multi-way tables - Causality, repeated measures, generalized least squares - mixed models, latent-class models, missing data, and algebraic statistics approach.

Books for Study and Reference

1. Agresti, Alan (1996). An Introduction to Categorical Data Analysis, Wiley.
2. Bergsma, W., Croon, M.A. and Hagenaars, J.A. (2009). Marginal Models: For Dependent, Clustered, and Longitudinal Categorical Data. Springer.
3. Bishop, Y.M., Fienberg, S.E. and Holland, P.W. (1975). Discrete Multivariate Analysis: Theory and Practice, MIT Press.
4. Edwards, D. (2000). Introduction to Graphical Modeling (Second Edition). Springer.
5. Fienberg, S.E. (1980). The Analysis of Cross-Classified Categorical Data. MIT Press.
6. Wasserman, L. (2004).All of Statistics: A Concise Course in Statistical Inference. Springer.
7. Whittaker, J. (1990). Graphical Models in Applied Multivariate Statistics. Wiley.

Elective III

Statistical Methods for Epidemiology

Unit I

Measures of disease frequency: Mortality/Morbidity rates- incidence rates- prevalence rates - Source of mortality morbidity statistics-hospital records - vital statistics records- Measures of accuracy or validity: sensitivity index - specificity index- Measure of Reliability.

Unit II

Epidemiologic concepts of diseases: Factors which determine the occurrence of diseases - models of transmission of infection - incubation period - disease spectrum and herd immunity.

Unit III

Observational studies in Epidemiology: Retrospective (case control) and prospective (cohort or longitudinal) studies - Measures of association: Relative risk, odds ratio, attributable risk- Statistical techniques used in analysis: Cornfield and Gartsmethod - Mantel-Haenszelmethod- Conditional and unconditional matching - Analysis of data from matched samples, logistic regression approach.

Unit IV

Experimental Epidemiology: Clinical & community trials - Statistical Techniques: Methods for comparison of two treatments - Crossover design with Garts and McNemars test - Randomization in a clinical trial - sequential methods in clinical trials - clinical life tables - assessment of survivability in clinical trials.

Unit V

Mathematical Modeling in Epidemiology:(deterministic and stochastic) simple epidemic model - generalized epidemic model- Reed-Frost and Green-wood models - models for carrier borne and host vector diseases - Estimation of latent and infectious periods - geographical spread of the disease - simulation of an epidemic.

Books for Study and Reference

1. Armitage. (1980). Sequential medical trials, Charles C. Thomas
2. Bailey, N.T.J. (1987). The Biomathematics of Malaria. Oxford University Press, Incorporated.
3. Fleiss, J.L. (1981): Statistical Methods for Rates and Proportions. John Wiley& Sons, Incorporated, New York.
4. Franeuthal. (1980). Mathematical Modernization in Epidemiology, Springer Verlag.
5. Gross and Clark. (1989). Survival Distributions- Reliability Application in Biomedical Sciences, University Microfilms.
6. Kahn, H.A. and C.T. Sempos. (2007). Statistical Methods in Epidemiology (Second Edition). Oxford University press, N.Y.
7. Kahn, H.A. (1983): An introduction to Epidemiologic methods. Oxford University press, N.Y. (Digitized 2007).
8. Lilienfeld and Lilenfeld. (1994): Foundations of Epidemiology (Third edition). Oxford University Press.

9. Macmahon, B. and Pugh, T.E. (1970). Epidemiology-Principles and methods, Little, Brown and Co. Boston/Massachusetts.

10. Pocock, S.J. (2004). Clinical Trials - A Practical Approach, John Wiley.

11. Fletcher, R. andFletcher, S.W. (2013). Clinical Epidemiology: The essentials. Lippincott Williams & Wilkins.

12. Rothman, K.J. (1986): Modern Epidemiology. Lippincott Williams & Wilkins.

13. Sackett, D. L (1991). Clinical Epidemiology - A Basic Science for Clinical Medicine. Little Brown.

Elective III

Statistical Data Analysis using R

Unit I

Data types in *r* numeric/character/logical; real/integer/complex strings and the paste command matrices, data frames, lists, setwd, read.table,read.csv,write.matrix,write.csv,creation of new variables, categorization, cut, factor; round, apply, creation of patterned variables - saving output to a file; source; print -saving workspace / history.

Unit II

Graphics in *r* - the plot command, histogram, bar plot, box plot - points, lines, segments, arrows, paste - inserting mathematical symbols in a plot, pie diagram, customization of plot-setting graphical parameters - text and mtext, the pairs command, colours and palettes, saving to a file; graphical parameters such as mar/mai/mfrow, xlab/ylab/las/xaxp/yaxp/xlim/ylim/cex/axis/tck/srt, main/title/legend/locator, identify.

Unit III

Basic statistics - *r* help-command help, help.search(), *r* mailing list - contributed documentation on cran - one and two sample *t* tests, Bartlett's test for variance, *f* - test for equality of variances, multi sample means, non-parametric tests, chi-squared tests - randomness, homogeneity, independence, exact tests and confidence intervals, checking the assumptions, distribution fitting.

Unit IV

Vector matrix operations - matrix operations - addition, subtraction, multiplication, linear equations and eigenvalues, matrix decomposition - lu, qr and svd and inverse, the linear model and qr decomposition, determinant, g inverse, finding a basis, orthonormalization, finding rank, the lm function; fitting a linear model; ANOVA / ANCOVA / regression

Unit V

Linear models - models, the summary function, goodness of fit measures, predicted values and residuals; residual plots, the ANOVA table, creating factors - *r* functions - random number generation and simulations - *r* libraries.

Books for Study and Reference

1. Purohit, S. G., Gore, S. D., and Deshmukh, S. R. (2009). Statistics Using R, Narosa Publishing House, New Delhi.
2. Quick, J. M. (2010). Statistical Analysis with R, Packt Publishing Ltd., UK.
3. Everitt, B. S., and Hothorn, T. (2010). A Handbook of Statistical Analyses Using R, Second Edition, Chapman and Hall, CRC Press.

Elective IV

Applied Regression Analysis

Unit I

Simple regression models with one independent variable, assumptions, estimation of parameters, standard error of estimator, testing the significance of regression coefficients, standard error of prediction.Testing of hypotheses about parallelism, equality of intercepts, congruence. Extrapolation, optimal choice of independent variable.

Unit II

Diagnostic checks and correction: graphical techniques, tests for normality, uncorrelatedness, homoscedasticity, lack of fit, modifications like polynomial regression, transformations on Y or X. Inverse regression.

Unit III

Multiple regression: Standard Gauss Markov Setup. Least square (LS) estimation, Error and estimation spaces. Variance - Covariance of LS estimators. Estimation of error variance, case with correlated observations. LS estimation with restriction on parameters. Simultaneous estimation of linear parametric functions.

Unit IV

Non-linear regression: Linearization transforms, their use & limitations, examination of non-linearity initial estimates, iterative procedures for NLS grid search, Newton - Raphson, steepest descent, Marquardt's methods. Logistic Regression: Logic transform, ML estimation, Tests of hypotheses, Wald test, LR test, score test, test for overall regression.

Unit V

Multiple logistic regressions, forward, backward method. Interpretation of parameters relation with categorical data analysis. Generalized Linear model: link functions such as Poisson, binomial, inverse binomial, inverse Gaussian and gamma.

Books for References

1. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis, Third Edition, John Wiley and Sons.
2. Montgomary, D. C., Peck, E. A., and Vining, G. G. (2012). Introduction to Linear Regression Analysis, Fifth Edition, ohn Wiley and Sons.
3. McCullagh, P., and Nelder, J. A. (1989). Generalized Linear Models, Second Edition, Chapman & Hall.
4. Ratkowsky, D.A. (1983). Nonlinear Regression Modelling, Marcel Dekker.
5. Hosmer, D.W., Lemeshow, S., and Sturdivant, R. X. (2013). Applied Logistic Regression, Third Edition, John Wiley and Sons.
6. Seber, G.E.F. and Wild, C.J. (2003). Nonlinear Regression, John Wiley and Sons.
7. Neter, J., Wasserman, W., and Kutner,M.H. (1989). Applied Linear Statistical Models, Second Edition, Irwin.

Elective IV

Time Series Analysis

Unit I

Models of Time Series – Additive and Multiplicative models – Analysis and forecasting – Elimination of trend – growth curve – Modified experimental curve (Method of three selected points only) - Gompertz curve- Logistic curve with examples.

Unit II

Stationary processes – Auto-covariance and autocorrelation functions and their properties – partial auto correlation function - Estimation of autocorrelation and its standard error – unit root test.

Unit III

Linear stationary models - stationary and invertability - Autoregressive and Moving average processes and their autocorrelation functions- Autoregressive moving average processes. Linear non-stationary models - Autoregressive integrated moving average processes – integrated moving average processes and Seasonal Autoregressive integrated moving average processes.

Unit IV

Box-Jenkins models: Identification techniques - Initial estimates for different processes – AR, MA, ARMA - choice between stationary and non-stationary models – model diagnostic - model multiplicity- Study of residuals and diagnostic checking - Use of computer packages for the above techniques.

Unit V

Introduction to spectral analysis of weakly stationary processes - periodogram and correlogram analysis including computations based on Fourier transform. Use of spectral representation to show the existence of autoregressive processes and their representation as one-sided moving average processes.

Books for Study and Reference

1. Anderson, T. W. (2011). The Statistical Analysis of Time Series. John Wiley & Sons.
2. Bloomfield, P. (2004). Fourier analysis of Time Series - An introduction (Second Edition). John Wiley & Sons.
3. Box, G. E. P. and Jenkins, G.M. and Reinsel,G.C.(2013). Time Series Analysis - Forecasting and Control (Fourth Edition). Holden- Day, San Francisco.
4. Brockwell, P. J. and Davis, R. A. (2002). Introduction to Time Series and Forecasting.Taylor & Francis.
5. Chatfield, C. (1978). The Analysis of Time Series - Theory and Practice (Third Edition). Chapman and Hall, London.
6. Gupta, S. C. and Kapoor, V.K. (2007). Fundamentals of Applied Statistics (Fourth Edition). Sultan Chand & Sons Company, New Delhi.
7. Hannan, E. J. (1960). Time Series Analysis, Methuen, London.
8. Kendall, M. G. and Stuart, A. (1976). The advanced theory of Statistics, Vol.3, Charles Griffin, London.
9. Kendall, M. G. (1974). Time Series. Charles Griffin, London.

10. Koopmans, L. H. (1995). The spectral analysis of Time Series. Academic press.

11. Montgomery, D. C. and Johnson, L. A. (1977). Forecasting and Time Series analysis. McGraw Hill.

12. Priestley, M. B. (1981). Spectral analysis and Time Series. Griffin, London.

Elective IV

Bayesian Methods

Unit I

Statistical decision theory – loss functions – 0-1, absolute error, squared error and LINEX loss functions – risk function – minimax solution – prior distribution – Bayes risk – Bayes solution to decision problems.

Unit II

Subjective probability – its interpretation and evaluation - Subjective determination of prior distributions - Improper prior, noninformative prior, invariant prior, Jeffreys noninformative prior and natural conjugate prior – family of distributions admitting natural conjugate prior.

Unit III

Point estimation – Bayes estimators under various loss functions – generalization to convex loss functions - Evaluation of the estimate in terms of posterior risk – comparison with frequentist methods.

Unit IV

Interval estimation – credible interval, highest posterior density region - Comparison of interpretation of the confidence co-efficient of an interval by Bayesian and frequentist methods – simple problems.

Unit V

Bayesian testing of statistical hypotheses – specification of the appropriate form of the prior distribution for Bayesian hypothesis testing problem – prior odds, posterior odds, Bayes factor and their computations to various hypotheses testing problems – specification of Bayes tests.

Books for Study and Reference

1. Bansal,A.K. (2007). Bayesian Parametric Inference. Narosa Publishing House, New Delhi.
2. Berger, J.O. (1985). Statistical Decision Theory and Bayesian Analysis (Second Edition). Springer Verlag, New York.
3. Bernardo, J.M. and Smith, A.F.M. (2000). Bayesian Theory. John Wiley & Sons, New York. (Reprint 2009).
4. Gelman,A., Carlin,J.B., Stern,H.B. and Rubin, D.B.(2013). Bayesian Data Analysis (Third Edition). CRC press.
5. Ghosh,J.K., Delampady, M. and Samanta, T. (2010). An Introduction to Bayesian Analysis: Theory and Methods. Springer Verlag, New York.
6. Lee, P.M. (2012). Bayesian Statistics – An Introduction (Fourth Edition). John Wiley & Sons, London.
7. Leonard, T. and J.S.J. Hsu. (1999). Bayesian Methods: An Analysis for Statisticians and Interdisciplinary Researchers. CambridgeUniversity Press, London.
8. Robert, C.P. (1994). The Bayesian Choice: A Decision-Theoretic Motivation (Second Edition). Springer Verlag, New York.
9. Robert,C.P. and Casella,G. (2004). Monte Carlo Statistical Methods (Second Edition). Springer Verlag, New York. (Reprint 2010)

Statistics Practical Using *R* - I

Exercise under Descriptive Statistics, Correlation, Regression and Test of significance.

1. Calculate the mean, standard deviation, variance and median.
2. Calculate the correlation coefficient.
3. Calculate the regression equations.
4. Calculate multiple regressions.
5. Calculate the logistic regression equations.
6. Problems for the one sample *Z*-test.
7. Problems for the *Z*-test for two sample proportions.
8. Problems for the paired *T*-test.
9. Problems for the chi-square test independence of attributes.
10. Problems for the chi-square goodness of fit test.

Statistics Practical Using *R* - II

Exercise under Standard Probability Distributions

1. Fitting of Binomial Distribution.
2. Fitting of Poisson Distribution.
3. Fitting of Normal Distribution.

Exercise under ANOVA and Design of Experiments

1. One – way and two – way analysis of variance

2. CRD, RBD and LSD

Exercise under statistical quality Control

Construction of control charts for mean, range and standard deviation of $\bar{X}$ and R charts.

Exercise under Reliability and Survival Analysis

Estimation of reliability function by the method of likelihood and the estimation of failure rates for the lifetime distributions - exponential, gamma and Weibull distributions.