BHARATHIAR UNIVERSITY, COIMBATORE 641 046

BRANCH II - STATISTICS

M.Sc., Statistics / M.Sc. Statistics (with Computer Applications)
(Choice Based Credit System)

(For the candidates admitted during the academic year 2019 – 2020 and onwards)

Objective of the Course

The course aims to instill and inspire the domain knowledge on theoretical and applied aspects of Statistics in a broader spectrum. It intends to impart awareness on the importance of the conceptual framework of statistics across diversified fields and to afford practical training on the applications of statistical methods for carrying out analysis of data using sophisticated statistical software like SAS, SYSTAT, SPSS, etc., and using the programming knowledge in R and C++. The course curriculum has been designed in such a way to cater the needs of the stakeholders to get placements in industries and institutions on successful completion of the course and to provide them ample skill and opportunities to meet the challenges at the national level competitive examinations like CSIR NET in Mathematical Sciences, SET, Indian Statistical Service (ISS) of UPSC, etc.

Eligibility Criteria for Admission

A candidate who has acquired a degree in B.Sc., Statistics or B.Sc., Mathematics with Statistics as an allied / ancillary subject or as one of the subjects or B. Sc., in Mathematics with Computer Applications having Statistics as one of subjects shall be permitted to join M. Sc., STATISTICS course.

A candidate who has acquired a degree in B.Sc., Statistics or B.Sc., Mathematics with Statistics as an allied / ancillary subject or as one of the subjects or B. Sc., Mathematics with Computer Applications having Statistics as one of subjects or B.Sc., in Computer Science with Statistics as one of the subjects or B.C.A., with Statistics as one of the subjects shall be permitted to join M. Sc., STATISTICS with (Computer Applications) course

Duration of the Course

The duration of the M. Sc., STATISTICS / M. Sc., STATISTICS with Computer Applications course is two years which comprise of four semesters. A candidate who has been admitted to the course shall appear all the four semester examinations during the course of study. On successful completion of all the examinations, he / she shall qualify himself/herself for the award of the degree in M.Sc., STATISTICS or M. Sc., STATISTICS (with Computer Applications).

Pattern of Choice Based Credit System

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 at 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 which include the mandatory online SWAYAM/MOOC course of 2 credits during the period of study. The break-up of total credits for the programme shall be as given under:

Core Papers – Theory	13 x 4 Credits = 52 Credits
Core Papers – Practical	04 x 4 Credits = 16 Credits
Elective Papers	03 x 4 Credits = 12 Credits
Core: Project/Dissertation	01 x 4 Credits = 04 Credits
Supportive Papers	02 x 3 Credits = 06 Credits
SWAYAM/MOOC Online Course	01 x 2 Credits = 02 Credits

Components for Internal Assessment

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	: 15
Marks for Assignments/Seminar	: 05 (Average of assignment and seminar marks)
Attendance	: 05

Distribution of Marks for Attendance

90% and above	: 5 Marks
Between 85% and 90%	: 4 Marks
Between 80% and 85%	: 3 Marks
Between 75% and 80%	: 2 Marks
Between 70% and 75%	: 1 Mark

Distribution of Continuous Internal Assessment Marks for Core - Practical Paper

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

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 course for the award of the degree in M.Sc., Statistics or M.Sc., Statistics (with Computer Applications).

A candidate who secures a minimum of 7.5 out of 10 CGPA (Cumulative Grade Point Average) and above 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 6.0 out of 10 CGPA and above 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 clears all the papers prescribed for the course in the FIRST APPEARANCE shall be eligible for Ranking/Distinction.

Pattern of Question Paper – (for core – practical subjects)

The question paper for each of the core - practical papers (Statistics Practical I and II, Programming Lab I and II, Statistical Software Practical using SPSS and MINITAB, and Statistical Software Practical using R Programming shall consist of four questions with internal choice. The maximum marks for each of the practical papers shall be 60. A candidate shall attend all the four questions, each of which shall carry 15 marks. The composition of the question paper shall be as given below:

Time: Three Hours Max. Marks: 60

Answer all the questions
Each question carries *fifteen* marks

Q. No. 1 – Q. No. 4 - Questions with internal choices (either (a) or (b) type)

Pattern of Question Paper – (for core - theory and elective subjects)

The question paper for each of the core and elective papers shall consist of three sections. While Section A shall contain 10 objective type questions, Section B and Section C shall contain questions of descriptive nature. Internal choice (either / or type) shall be given in Section B and Section C. In Section A, there shall be two questions each with four multiple choices 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. The composition of the question paper shall be as given below:

Time: Three Hours Max. Marks: 75

Section A – (10 x 1 = 10)
Answer *All* the questions
Each question carries *one* mark

Q. No.1. – Q. No. 10 - Objective questions with four multiple choices

Section B – (5 x 5 = 25)
Answer all the questions
Each question carries *five* marks

Q. No. 11 – Q. No. 15 - Questions with internal choices (either (a) or (b) type)

Section C – (5 x 8 = 40)
Answer all the questions
Each question carries *eight* marks

Q. No. 15 – Q. No. 20 - Questions with internal choices (either (a) or (b) type)

Pattern of Question Paper – (for supportive subject)

The question paper for each of the supportive papers shall consist of three sections. While Section A shall contain 5 objective type questions, Section B and Section C shall contain questions of descriptive nature. Internal choice (either / or type) shall be given in Section B and Section C. In Section A, there shall be one question each with four multiple choices from each of the five units. In Sections B, there shall be one question with internal choice (either/or type) from each of the five units and in Section C, there shall be three questions with internal choice (either/or type from all the five units. The composition of the question paper shall be as given below:

Time: Two Hours Max. Marks: 38

Section A – (5 x 1 = 5)
Answer *All* the questions
Each question carries *one* mark

Q. No.1. – Q. No. 5 - Objective questions with four multiple choices

Section B – (5 x 3 = 15)

Answer all the questions

Each question carries *three* marks

Q. No. 6 – Q. No. 10 - Questions with internal choices (either (a) or (b) type)

Section C – (3 x 6 = 18)

Answer all the questions

Each question carries *six* marks

Q. No. 11 – Q. No. 13 - Questions with internal choices (either (a) or (b) type)

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BRANCH II - STATISTICS

Course Title: M.Sc. (Statistics with Computer Applications) | Course Code: 17STAB

(For the candidates admitted during 2019-2020 and onwards)

List of Core/Elective/Supportive Subjects to be offered

CORE Subjects

1. Real Analysis and Linear Algebra
2. Measure and Probability Theory
3. Distribution Theory
4. Sampling Theory and Methods
5. Statistical Estimation Theory
6. Multivariate Analysis
7. Statistical Quality Control and Reliability
8. Operations Research
9. Programming Lab I: Object Oriented Programming with C++
10. Testing Statistical Hypotheses
11. Linear Models and Design of Experiments
12. Programming in R
13. Statistical Software Practical using SPSS and MINITAB
14. Stochastic Processes
15. Biostatistics and Survival Analysis
16. Programming Lab II: Computational Statistics
17. Statistical Software Practical using R
18. Project & VIVA-VOCE

ELECTIVE Subjects (for students of M.Sc., Statistics with Computer Applications)

1. Object Oriented Programming with C++
2. Official Statistics
3. Computer Simulation and Modeling
4. Data Mining
5. Applied Regression Analysis

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BRANCH II - STATISTICS

Course Title: M.Sc. (Statistics with Computer Applications) | Course Code: 17STAB

(For the candidates admitted during 2019-2020 and onwards)

Course Structure and Scheme of Examinations

Semester I						
Subject	Code	Title of the Papers	Credits	Internal Marks	External Marks	Total Marks
Core	17S13A	Real Analysis and Linear Algebra	4	25	75	100
Core	17S13B	Measure and Probability Theory	4	25	75	100
Core	17S13C	Distribution Theory	4	25	75	100
Core	17S13D	Sampling Theory and Methods	4	25	75	100
Elective	17S13EA	Elective I	4	25	75	100
Supportive	Supportive	Offered by other Departments	2	12	38	50
		Total	**22**			**550**
Semester II						
Subject	Code	Title of the Papers	Credits	Internal Marks	External Marks	Total Marks
Core	17S23A	Statistical Estimation Theory	4	25	75	100
Core	17S23B	Multivariate Statistical Analysis	4	25	75	100
Core	17S23C	Statistical Quality Control and Reliability	4	25	75	100
Core	17S23D	Operations Research	4	25	75	100
Practical	17S2P1	Programming Lab I: Object Oriented Programming with C++	4	40	60	100
Supportive	Supportive	Offered by other Departments	2	12	38	50
		Total	**22**			**550**
Semester III						
Subject	Code	Title of the Papers	Credits	Internal Marks	External Marks	Total Marks
Core	17S33A	Testing Statistical Hypotheses	4	25	75	100
Core	17S33B	Linear Models and Design of Experiments	4	25	75	100
Core	17S33C	Programming in R	4	25	75	100
Elective	17S33EB	Elective II	4	25	75	100
Practical	17S3P2	Statistical Software Practical using SPSS and MINITAB	4	25	75	100
Supportive	Supportive	Offered by other Departments	2	12	38	50
		Total	**22**			**550**
Semester IV						
Subject	Code	Title of the Papers	Credits	Internal Marks	External Marks	Total Marks
Core	17S43A	Stochastic Processes	4	25	75	100
Core	17S43B	Biostatistics and Survival Analysis	4	25	75	100
Elective	17S43EC	Elective III	4	25	75	100
Practical	17S4P3	Programming Lab II: Computational Statistics	4	40	60	100
Practical	17S4P4	Statistical Software Practical using R	4	40	60	100
Project	17S4PV	Project and Viva-voce*	4	25	75	100
		SWAYAM – MOOC – Online Course*	2			50
		Total	**26**			**650**

*SWAYAM – MOOC – online course shall be of duration at least 4 weeks with at least 2 credits. The course shall be mandatory and shall be completed within third semester (i.e., before the beginning of fourth semester).

Distribution of Marks and Credits

Subjects	**Marks**	**Credits**
Core	1800	72
Elective	300	12
Supportive	150	06
SWAYAM/MOOC Course	50	02
Total	**2300**	**92**

17S13A	Real Analysis and Linear Algebra	Core 1

Unit I

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

Unit II

Sequences and Infinite Series: Boundedness and limit of a sequence - 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

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 IV

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 V

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.

Books for Study

1. Ajit Kumar and Kumaresan, S. (2014). A Basic Course in Real Analysis, Chapman and Hall/CRC Press.
2. Arora, S. (1988). Real Analysis, Satya Prakashan Mandir, New Delhi.
3. Goldberg, R. R. (1976). Methods of Real Analysis, Oxford & IBH Publishing Company, New Delhi.
4. Hoffman, K., and Kunze, R. (1975). Linear Algebra, Second Edition, Prentice Hall of India, New Delhi.
5. Kumaresan, S. (2000). Linear Algebra: A Geometric Approach, PHI Learning.
6. Malik, S.C., and Arora, S. (2009). Mathematical Analysis, Second Edition, New Age International, New Delhi.
7. Rao, .A. R., and Bhimasankaram, P. (2000). Linear Algebra, Second Edition, Hindustan Book Agency, Hyderabad.
8. Vasishta, A. R. (2005). Matrices. Krishna Prakashan Mandir, New Delhi.

Books for Reference

1. Apostol, T. M. (1986). Mathematical Analysis, Second Edition, Addison-Wesley, New York (Twentieth Reprint, 2002).
2. Graybill, F.A. (1983). Matrices and Applications in Statistics, Wadsworth Publishing Company, Belmont, California, USA.
3. Hohn, F.E. (1971). Elementary Matrix Algebra, Amerind Publishing Co. Pvt. Ltd., New Delhi.
4. Rudin, W. (1985). Principles of Mathematical Analysis, McGraw-Hill, New York.
5. Searle, S.R. (1982). Matrix Algebra Useful for Statistics, John Wiley, New York.

17S13B	Measure and Probability Theory	Core 2

Unit I

Sets: Finite and infinite sets, Limit superior, limit inferior and limit of a sequence of sets. Field sigma field and Borel field – Functions and inverse functions – Set functions – Measure: Measure space, Measurable functions, Combinations of measurable functions, Sequences of measurable functions, Pointwise convergence, Convergence in measure.

Unit II

Integration: Integrable simple functions, Sequences of integrable simple functions, Integrable functions, Sequences of integrable functions, Properties of integrals – Signed Measures – Absolute Continuity – Radon – Nikodym theorem (Statement only) – Product measures – Fubini's theorem (Statement only).

Unit III

Random variables – Limits of random variables – Probability, probability space, induced probability space and discrete probability space – Properties. Distribution functions. Expectation and Conditional Expectation – Properties – Inequalities: Jensen's, Holder's, Minkowski's, Cauchy –Schwartz's inequalities - Basic Inequality – Chebychev's and Markov's inequalities.

Unit IV

Convergence of random variables: Convergence in probability, convergence almost surely, convergence in distribution, Convergence in rth mean, monotone convergence theorem – Definition and properties of characteristic functions – Inversion formula – Problems - Borel 0 - 1 law- Borel Cantelli lemma – Uniqueness theorem – Helly-Bray lemma.

Unit V

Law of Large Numbers : Weak and Strong Law of Large Numbers – Bernoulli's Weak Law of Large Numbers - Kolmogorov's Strong law of large numbers – Central limit theorem – Lindeberg – Levy's central limit theorem - Liaponov's central limit theorem - Lindberg – Feller's central limit theorem (Statement only)

Books for Study

1. Basu, A. K. (2012). Measure Theory and Probability, Prentice Hall India Learning Private Limited, New Delhi.
2. Bhat, B. R. (2009). Modern Probability Theory – An Introductory Text Book, Third Edition (Reprint), New Age International Private Ltd., New Delhi.
3. Dudewicz, E.J., and Mishra, S. N. (1988). Modern Mathematical Statistics, John Wiley & Sons, New York.
4. Malik, G. S., Gupta, P. P., and Mittal, S. K. (2018). Measure Theory, Eighth Edition, Pragati Prakahsan.
5. Mukhopadhyay, P. (2006). Mathematical Statistics, Third Edition, Books and Allied (P) Limited, Kolkata. .
6. Rohatgi V. K. (1976). Introduction to Probability Theory and Mathematical Statistics, John Wiley & Sons, NY.
7. Rohatgi, V. K., and Saleh, A.K.M.E. (2015), An Introduction to Probability and Statistics, Third Edition, John Wiley & Sons, NY.

Books for Reference

1. Feller, W. (2008). Introduction to Probability Theory and its Applications, Vol. I, Third Edition, Wiley, NY. .
2. Rao, C. R. (2001). Linear Statistical Inference and Its Applications, Second Edition, Wiley – Interscience, NY.
3. Halmos, P. R. (1978). Measure Theory, (First Edition in 1950), Second Printing, Springer-Verlag, NY.

17S13C	Distribution Theory	Core 3

Unit I

Probability distributions: Cauchy distribution – Laplace distribution - Pareto distribution – Lognormal distribution – Power series distribution – Logarithmic series distribution – Distribution of functions of random variables

Unit II

Bivariate binomial, Bivariate Poisson and Bivariate normal distributions - Concept of truncated distribution – compound distribution – mixture distribution and their properties.

Unit III

Non-central t, chi-square and F distributions and their properties.

Unit IV

Order Statistics: Distribution of order statistics - Joint distribution of order statistics – Asymptotic distribution of rth order statistics - Joint distribution of range and mid range.

Unit V

Distribution of Quadratic forms – Properties – Cochran's Theorem – Empirical Distributions – Properties.

Books for Study

1. Rohatgi V. K. (1976). Introduction to Probability Theory and Mathematical Statistics, John Wiley & Sons, NY.
2. Johnson, N. L., Kemp, A.W., and Kotz, S. (2005). Univariate Discrete Distributions, Third Edition, John Wiley and Sons, New York.
3. Johnson, N. L., Kotz, S., and Balakrishnan, N. (2004). Continuous Univariate Distributions. Vol. I, John Wiley and Sons (Asia), Singapore.
4. Johnson, N. L., Kotz, S., and Balakrishnan, N. (2014). Continuous Univariate Distributions, Vol. II. John Wiley and Sons (Asia), Singapore.

Books for Reference

1. Hogg, R.V., McKean, J. W., and Craig, A. T. (2012). Introduction to Mathematical Statistics, Seventh Edition, Pearson Education, London.
2. Johnson, N. L., and Kotz, S. (1972). Distributions in Statistics, Princeton University Press, Princeton.

17S13D	Sampling Theory and Methods	Core 4

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.

Unit II

Simple Random Sampling (with and without replacement): Notations and terminology - Estimates of population total, mean and their variances and standard errors – Pooling of estimates - Determination of sample size. Simple random sampling for attributes -

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: Probability proportional to size (PPS) sampling (with and without replacement) – Stratified PPS – Selection procedures – Ordered and unordered estimates – Desraj, Horwitz – Thompson and Murthy's estimates. Ratio Estimates – Methods of estimation, approximate variance of the Ratio Estimate - Regression Estimators – Difference Estimators, Regression Estimators in Stratified Sampling..

Books for Study

1. Cochran, W.G. (1977). Sampling Techniques, Third Edition, John Wiley & Sons, NY.
2. Singh D., and Chowdhary, F. S. (2018). Theory and Analysis of Sample Survey Design, New Age International Private Ltd., New Delhi.
3. Des Raj (1978), Sampling Theory, Tata-McGraw Hill, New Delhi.

Books for Reference

1. Sukhatme, P. V., and Sukhatme, B. V. (1970). Sampling Theory of Surveys with Applications, Asia Publishing House, New Delhi.
2. Sampath, S. (2000). Sampling Theory and Methods, Narosa Publishing Company, New Delhi.
3. Murthy, M. N. (1967). Sampling Theory and Methods, Statistical Publishing Society, Calcutta.

17S23A	Statistical Estimation Theory	Core 5

Unit I

Estimation and point estimation - Sufficiency – Factorization Theorem – Minimal sufficiency, likelihood equivalence – Completeness – Uniformly minimum variance unbiased estimator – Rao - Blackwell and Lehmann - Scheffe theorems.

Unit II

Mean-squared error, Fisher's information measure. Cramer-Rao inequality, Bhattacharya inequality, Chapman-Robbins inequality - Fisher's information matrix-simultaneous of parameters in normal(univariate and bivariate) distribution.

Unit III

Methods of point estimation-maximum likelihood method (asymptotic properties of ML estimators are not included), method of moments, method of minimum chi-square and modified minimum chi-square.

Unit IV

Consistency and CAN estimators. Asymptotic properties of maximum likelihood estimators. Example of consistent but not asymptotic normal estimators from Pitman family. Fisher's lower bound for asymptotic variance. Asymptotic relative efficiency. Method of least squares.

Unit V

Interval estimation: Confidence level and confidence coefficient. Duality between acceptance region of a test and a confidence interval. Pivotal quantity method. Shortest length confidence intervals.

Construction of confidence intervals for population proportion (small and large samples) and between two population proportions (large samples) - Confidence intervals for mean, variance of a normal population, difference between mean and ratio of two normal populations.

Books for Study

1. Goon, A. M., Gupta, M. K., and Dasgupta, B. (1989). An Outline of Statistical Theory-Vol.II, World Press, Calcutta. .
2. Kale, B. K. (1999). A First Course on Parametric Inference, Narosa Publishing House, New Delhi.
3. Rohatgi, V. K. (1976). Introduction to Probability Theory and Mathematical Statistics, John Wiley & Sons, NY.

Books for Reference

1. Dudewicz, E. J., and Mishra, S. N. (1988). Modern Mathematical Statistics, John Wiley & Sons, NY.
2. Lehman, E. L., and Cassella, G. (1998). Theory of Point Estimation, Second Edition, Springer, NY.

17S23B	Multivariate Statistical Analysis	Core 6

Unit I

Multivariate Normal Distributions - Marginal and Conditional Distributions - Characteristic Function and Moments - Distribution of Linear Combinations of Multivariate Normal Vector - Determination of Mean and Covariance Matrix of Multivariate Normal Distribution.

Unit II

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 as a chi - square distribution - Inference concerning the sample mean vector when covariance matrix is known.

Unit III

Wishart Distribution – Characteristic function and properties. Hotelling's T^2 Distribution – Properties and Applications - Two sample problems with unequal covariance matrices - Likelihood Ratio Criterion - Mahalanobis D^2 Distribution - Relationship between T^2 and D^2 statistics – Behrens-Fisher problem.

Unit IV

Discriminant Analysis: Objectives and assumptions - Fisher's Discriminant Function - Problem of Classification with Two or More Populations - Cluster Analysis: Objectives, Assumptions, Research design. – Formation of clusters – Clustering algorithm.

Unit V

Principal components: Objectives – Extraction of principal components - Factor analysis: Objectives – Estimation of factor loadings - Canonical variables and canonical correlations: Determination of canonical correlation coefficients. Concepts of multidimensional scaling and correspondence analysis.

Books for Study

1. Anderson, T.W. (2003). An Introduction to Multivariate Statistical Analysis, Third Edition, Wiley – Interscience, NY.
2. Johnson, R. A., and Wichern, D. W. (2013). Applied Multivariate Statistical Analysis Sixth Edition, Pearson New International Edition.
3. Jambu, M., and Lebeaux, M.-O. (1983). Cluster Analysis and Data Analysis, North-Holland, NY.

Books for Reference

1. Kshirsagar, A. M. (1972), Multivariate Analysis, Marcel Decker, Inc., NY.
2. Morrison, D. F. (2004). Multivariate Statistical Methods, Fourth Edition, Duxbury Press, CA,
3. Afifi, A. A., and Azen, S. P. (1979): Statistical Analysis - A Computer Oriented Approach, Second Edition, Academic Press, NY.
4. Giri, N. C., (1977). Multivariate Statistical Inference, Academic Press, NY..
5. Rencher, A. C., (2002), Methods of Multivariate Analysis, Second Edition, John Wiley & Sons, NY.

17S23C	Statistical Quality Control and Reliability	Core 7

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 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. Construction of Moving range, moving-average and geometric moving-average control charts..

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 – Decision Lines - OC and ASN functions.

Unit V

Concept of reliability, components and systems, coherent systems, reliability of coherent systems - Reliability function, hazard function, hazard rate, failure rates - IFR and DFR distributions - Common life distributions: exponential, Weibull, gamma distributions - Estimation of parameters. - Reliability of a system with independent components. Series, parallel and mixed systems with several components.

Books for Study

1. Duncan, A. J. (2003.). Quality Control and Industrial Statistics, Irwin-Illinois, US.
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. Ross, S. M. (2009). Introduction to Probability Models, Tenth Edition, Academic Press, MA, US.
5. 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. Schilling, E. G., and Nuebauer, D.V. (2009). Acceptance Sampling in Quality Control Second Edition, CRC Press, New York.
5. Wetherill, G.B. (1977). Sampling Inspection and Quality Control, Second Edition, Chapman and Hall, London.

17S23D	Operations Research	Core 8

Unit I

Review of linear programming problems – Simplex algorithm – Use of artificial variables - Two-phase method and Big-M method - Degeneracy in LPP. Duality – Interpretation of duality - Dual Simplex Method.

Unit II

Integer programming problem (IPP) – Pure and mixed integer programming problems - Gomory's constraints and cutting plane algorithm - Mixed IPP – Branch and Bound technique. Dynamic programming problem (DPP) - Principle of optimality – Recursive equation approach Characteristics of DPP.

Unit III

Non-Linear Programming (NLPP): Formulation of NLPP - Constrained optimization problems – Graphical solution - Kuhn-Tucker conditions. Quadratic Programming: Wolf's and Beale's methods.

Unit IV

Inventory control: Analytic structure of Inventory Problems, Concept of economic order quantity, its sensitivity analysis and extensions allowing quantity discounts and shortages, Deterministic and probabilistic inventory models - Models with random demand, and static risk models - Multi-item deterministic inventory problems.

Unit V

Queueing theory: Queueing systems, queueing models, classification of models - M/M/1, M/M/C and M/C/1 queues and their steady state solutions, Waiting Time Distributions for M/M/1 and M/M/C Models. Network scheduling by PERT/CPM, PERT: Basic components, determination of flows and critical path.

Books for Study

1. Hillier, F. S. and Leiberman, G. J. (1990). Introduction to Operations Research, Fifth Edition, McGraw-Hill, NY.
2. Kanti Swarup, Gupta, P. K., and Man Mohan. (2017). Operations Research, Nineteenth Edition, Sultan Chand & Sons, New Delhi.
3. Taha, H. A. (1982). Operations Research: An Introduction, Third Edition, McMillan Publishing Co., Inc., London.
4. Sharma, S. D. (2017). Operations Research: Theory, Methods and Applications, Kedar Nath, Ram Nath and Co, Meerut.

Books for Reference

1. Saaty, T. L. (1961). Elements of Queueing Theory, McGraw-Hill Co., NY.
2. Wagner, H. M. (1980). Principles of Operations Research with Application to Managerial Decisions, Second Edition, Prentice Hall India Learning Private Limited, New Delhi.

17S2P1	Programming Lab I	Core 9

The maximum marks for continuous internal assessment and end semester University examination for Programming Lab I shall be fixed as 40 and 60, respectively. The continuous internal assessment shall involve test and record work. The question paper at the end semester examination shall consist of four questions with internal choice. A candidate shall attend all the four questions, each of which shall carry 15 marks. The examination shall be conducted at the end of Semester II. Problems relating to the following topics which are covered in Semester I and Semester II shall form the basis for setting the question paper:

Object Oriented Programming with C++

1. Measures of Central Tendency, Dispersion, Skewness and Kurtosis
2. Simple, Partial, Multiple Correlation Coefficients, Regression coefficients and least squares estimates
3. Smallest and largest element of a given array of numbers, Sorting of numbers, Matrix operations (Algebraic operations: addition, subtraction and multiplication of matrices, verification of properties, inverse of a given matrix)
4. Generating random numbers using standard discrete and continuous distributions, computation of probability and cumulative probabilities of a given distribution
5. Computation of unbiased estimates of population total, mean and variance under simple random sampling with/without replacement, and verification of properties.
6. Computation of confidence limits for mean, variance and ratio of variances based on samples from a normal population for given critical values of χ^2, t, F and Z statistics
7. Computation of sample mean vector and covariance matrix of multivariate normal population, and computation of T^2 and D^2 statistics
8. Computation of control limits of control charts for variables and attributes, computation of acceptance probabilities for single sampling plan and construction of OC, ATI and AOQ curves.

17S33A	Testing Statistical Hypotheses	Core 10

Unit I

Testing of hypotheses: simple and composite hypotheses, two types of errors, level of significance, randomized and non-randomised 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-Chi-square and Kolmogorov-Smirnov tests. Test for randomness. Wilcoxon's signed-rank test. Kolmogorov-Smirnov two sampler test. Mann-Whitney U test. Kruskal-Wallis 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

1. Rohatgi, V. K. (1976). Introduction to Probability Theory and Mathematical Statistics, John Wiley & Sons, NY.
2. Lehmann, E. L. (1986). Testing Statistical Hypotheses, Second Edition, John Wiley & Sons, NY.
3. Goon, A. M., Gupta, M. K., Das Gupta. B. (1973). An outline of Statistical Theory, Vol. II, World Press, Calcutta.
4. Rajagopalan, M., and Dhanavanthan, P. (2012). Statistical Inference, PHI Learning Pvt., Ltd., New Delhi.
5. Gupta, S. C., and Kapoor, V. K. (2002), Fundamentals of Mathematical Statistics, Sultan Chand & Sons, New Delhi.

Books for Reference

1. Conover, W. J. (1980). Practical Nonparametric Statistics, Second Edition, John Wiley & Sons, NY.
2. Gibbons, J. D. and Chakrabarthi, S. (2010). Nonparametric Statistical Inference, Fifth Edition, Chapman and Hall/CRC Press, FL.
3. Kale, B. K. (1999). A First Course on Parametric Inference, Narosa Publishing House, New Delhi.
4. Wald, A. (1982) Sequential Analysis .John Wiley & Sons, NY.

17S33B	**Linear Models and Design of Experiments**	**Core 11**

Unit I

Linear Models - Assumptions on Error Components - Fixed/Mixed and Random Component Models – Generalized linear model - Gauss-Markov set up – Estimation – Least square method – MLE method - Gauss-Markov theorem-BLUE - Test for Linear Hypothesis - Principles of Experimentation - Review of Basic Designs and CRD-RBD-LSD.

Unit II

Multiple Comparison and Multiple Range Tests: Need – Tukey's Test – Fisher's Least Significance Difference method, Duncan's multiple range test, Newton-Kauls test - Analysis of Covariance – One-way and two-way - Analysis of Graeco Latin Squares, Cross Over Designs, Split Plot and Strip Plot Designs.

Unit III

Factorial Experiments – Advantages and limitations – main effects and interaction effects - Analysis of 2^n, 3^n, s^n and and n x p Asymmetrical Factorial Experiments – Concept and Principle of total, partial and balanced Confounding in Symmetrical Factorial experiments –Advantages and disadvantages of confounding - Analysis of confounded 2^n and 3^n factorial experiments.

Unit IV

Concept of Fractional Replication in Symmetrical Factorial experiments - 1/2 and 1/4 replicate of 2^n, 1/3 replicate of 3^n experiments - Construction and Analysis – Concept of response surface experiments - First order Response surface designs – steepest ascent method – Second order Response surface designs.

Unit V

Incomplete Block Designs, Incidence matrix and its properties, C- matrix and its significance - Concept of Connectedness and Orthogonality – Balanced Incomplete Block Designs parametric relationships – inter and intra block analyses - Partially Balanced Incomplete Block Design and its analysis - Youden Square Design - Simple and Balanced Lattice Designs.

Books for Study

1. Montgomory, D.C. (2012). Design and Analysis of Experiments, Eighth Edition, John Wiley & Sons, NY.
2. Das, M. N., and Giri, N. C. (2011). Design and Analysis of Experiments, Second Edition, New Age International Private Ltd., New Delhi
3. Graybill, F.A. (1961): An Introduction to Linear Statistical Models, McGraw Hill Co., London.
4. Graybill, F. A. (2000). Theory and Applications of Linear Models, Duxbury Press, First Edition, MA.

Books for Reference

1. Fisher, R.A. (1966). The Design of Experiments, 8th Edition, Oliver and Boyd, London.
2. Federer, W. T. (1967). Experimental Design: Theory and Application, Indian Edition, Oxford and IBH Publishing Co., New Delhi.
3. Kempthorne, O. (1965). The Design and Analysis of Experiments, Wiley Eastern India Limited, New Delhi
4. Cochran, W.G. and Cox, G.M. (1992). Experimental Designs, Second Edition, John Wiley & Sons, New York.
5. Nigam, A. K., Puri, P. D., and Gupta, V. K. (1988). Characterizations and Analysis of Block Designs, John Wiley & Sons, NY.
6. Paneerselvam, R. (2012). Design and Analysis of Experiments, PHI Learning Private Ltd., New Delhi.
7. John, P.W.M. (1971). Statistical Design of Experiments, Macmillan Co., NY.
8. Joshi, D.D. (1987). Linear Estimation and Design of Experiments, First Edition, New Age International (P) Ltd, New Delhi.
9. Searle, S.R. and Gruber, M. H. J. (2016). Linear Models, Second Edition, John Wiley & Sons, Inc., New York.

17S33C	Programming in R	Core 12

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 & 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.

17S3P2	**Statistical Software Practical using SPSS and MINITAB**	**Core 13**

The maximum marks for continuous internal assessment and end semester University examination for Statistical Software Practical I shall be fixed as 40 and 60, respectively. The continuous internal assessment shall involve test and record work. The question paper at the end semester examination shall consist of four questions with internal choice. A candidate shall attend all the four questions, each of which shall carry 15 marks. The examination shall be conducted at the end of Semester II. Problems relating to the following topics which are taught using statistical software namely SPSS and MINITAB shall form the basis for setting the question paper:

1. Classification, diagrams, graphical representation of data and descriptive statistical measures
2. Calculation of probabilities under various distributions and generating random samples from probability distributions
3. Correlation and regression: Simple, partial and multiple correlation coefficients, simple linear and multiple regression, curve fitting, time series and forecasting models
4. Confidence intervals for mean, variance and proportions, tests of significance based on normal, t, chi-square, F and Z statistics
5. Non-parametric tests: Run, sign and median tests, test based on Kruskal – Wallis statistics, Freedman's test
6. Experimental Design: One way ANOVA-two way ANOVA-factorial designs– Multiple comparison tests
7. Multivariate :Principal component analysis, factor analysis, cluster analysis and discriminant analysis
8. Statistical Quality Control charts – Determination of parameters for constructing basic control charts, such as $\overline{X}$, R, S, p and c charts.

17S43A	Stochastic Processes	Core 14

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 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.

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

Stationary Processes: Discrete Parameter Stochastic Process – Application to Time Series. Auto-covariance and Auto-correlation 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

1. Karlin, S. and Taylor, H.M. (1975): A First Course in Stochastic Processes, Second Edition, Academic Press, Inc., NY
2. Medhi, J. (2017): Stochastic Processes, Fourth Edition, New Age International Private Ltd., New Delhi.
3. Box, G.E.P., Jenkins, G.M. and Reinsel, G.C. (1994) Time Series Analysis; Forecasting and Control. Third Edition, Prentice Hall, Englewood Cliff, NJ.

Books for Reference

1. Granger, C. W. J., and Newbold, P. (1984): Forecasting Econometric Time Series, Second Edition, Academic Press Inc., NY.
2. Anderson, T.W., (1971): The Statistical Analysis of Time Series, John Wiley & Sons, NY. (Latest Edition: 1994: Wiley Interscience)
3. Adke, S. R., and Manjunath, S. A. (1984): An Introduction to Finite Markov Processes, Wiley Eastern, New Delhi.
4. Parzen, E. (1962): Stochastic Processes, Holden-Day, Oakland, CA. (Latest Edition: 2015: Dover Books on Mathematics, Dover Publications).

17S43B	Biostatistics and Survival Analysis	Core 15

Unit I

Introduction to Biostatistics - Clinical Trials - Goals of Clinical Trials - Phases of Clinical Trials - Classification of Clinical Trials - Randomization: Fixed Allocation, Simple, Blocked, Stratified, Baseline Adaptive and Response Adaptive - Blinding: Single, Double and Triple - Designs for Clinical Trials: Parallel Groups Design, Cluster Randomization Designs, Crossover Designs.

Unit II

Multiple Regression – Assumptions – uses – Estimation and interpretation of coefficients – Testing the regression coefficients – Coefficient of determination – Testing model adequacy. Logistic regression: Introduction – Logistic regression model – relative risk – logit – odds ratio – properties of odds ratio – relationship between odds ratio and relative risk – Maximum Likelihood estimates and interpretation – Test for coefficients - Test of overall regression and goodness of fit using Maximum Likelihood technique – Inference for Logistic regression – Deviance statistics, Wald test, LR test and score test.

Unit III

Introduction to Survival analysis - terminology and functions of survival analysis - goals - Basic data layout - Censoring-different types of censoring - Parametric survival models based on basic life time distributions - Exponential, Weibull, Gamma and Log- logistic.

Unit IV

Kaplan-Meier's method - general features - the log rank test for two groups, several groups - alternatives to the log rank test - Cox PH model and its features - ML estimation of the Cox PH model-Hazard Ratio-adjusted survival curves-Cox likelihood.

Unit V

Evaluating the proportional Hazards Assumptions - Overview - graphical approach - log-log plots - Observed versus expected plots- time - dependent covariates - Stratified Cox Procedure - hazard function - Extension of the Cox PH Model - hazard ratio formula - extended Cox likelihood.

Books for References

1. Chow, S. C., and Liu, J. P. (2004). Design and Analysis of Clinical Trials: Concepts and Methodologies, Second Edition, Wiley – Interscience, John Wiley & Sons, NJ.
2. Friedman, l. M., Furberg, C. D., and DeMets, D. L. (2010), Fundamentals of Clinical Trials, Fourth edition, Springer – Verlag, NY.
3. Das, M. N., and Giri, N. C. (2011). Design and Analysis of Experiments, Second Edition, New Age International Private Ltd., New Delhi.
4. Lee, E. T., and Wang, J. W. (2013). Statistical methods for Survival Data Analysis, Fourth Edition, Wiley, NY.
5. *van* Belle, G., Fisher, L. D., Heagerty, P. J., and Lumley, T. (2004). Bio Statistics - A Methodology for the Health Science, Second edition, Wiley, NY.
6. Daniel, W. W. (2013). Bio Statistics: Basic Concepts and Methodology for the Health Sciences, Tenth Edition, John Wiley & Sons, NY.
7. Kleinbaum, D. G., and Klein, M. (2012): Survival Analysis: A Self-Learning Text, Third Edition, Springer – Verlag, NY.
8. Klein, J. P. and Moeschberger, M. L. (2003). Survival analysis: Techniques for Censored and Truncated data, Second Edition, Springer – Verlag, NY.

17S4P3	**Programming Lab II: Computational Statistics**	**Core 16**

The maximum marks for continuous internal assessment and end semester University examination for Programming Lab II shall be fixed as 40 and 60, respectively. The continuous internal assessment shall involve test and record work. The question paper at the end semester examination shall consist of four questions with internal choice. A candidate shall attend all the four questions, each of which shall carry 15 marks. The examination shall be conducted at the end of Semester IV. The following topics on computational and graphical approaches for solving statistical problems will be covered in this practical oriented paper and shall form the basis for setting the question paper.

1. Introduction to R and data manipulation using R
2. Visualization of data
3. Solving simultaneous linear algebraic equations based on matrix computation
4. Solving polynomial equations using numerical methods
5. Generating random numbers from standard discrete and continuous distributions
6. Markov Chain Monte Carlo techniques
7. Resampling methods, Jackknife and bootstrap methods
8. Maximum likelihood estimates

17S4P4	**Statistical Software Practical using R**	**Core 17**

The maximum marks for continuous internal assessment and end semester University examination for Statistical Software Practical II shall be fixed as 40 and 60, respectively. The continuous internal assessment shall involve test and record work. The question paper at the end semester examination shall consist of four questions with internal choice. A candidate shall attend all the four questions, each of which shall carry 15 marks. The examination shall be conducted at the end of Semester IV. The aim of this paper is to utilize theoretical knowledge gained and to develop computational and technical skills for real life applications emphasizing the importance of R programming. Problems relating to the following topics shall form the basis for setting the question paper:

1. Using R command-Operations on vectors, logical vector, index vector and matrices. Creating and Manipulation of data frames, using various user defined functions..
2. Graphical procedures - Bar chart, Box plots, Histograms using single & multiple groups.
3. Calculations of probability functions and generation of random samples for various discrete and continuous distributions.
4. Writing R functions for descriptive statistics, correlations and regression co-efficients.
5. Statistical Inference: Parametric and Non-Parametric test. Experimental design for One way and Two way ANOVA
6. Execution of control charts and Acceptance sampling plans
7. Using R functions writing program for Linear models and least square techniques.
8. Multivariate techniques.

17S4PV	**Project and Viva-Voce**	**Core 18**

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 submit three copies of the report of the project/dissertation work at the end of the fourth semester at least two weeks before the last working day and shall have to appear for a viva-voce examination. The report shall be evaluated and viva-voce examination shall be conducted jointly by an External Examiner and the Project Guide. The maximum marks for the project/dissertation report and viva – voce examination shall be fixed as 100, which is split with the following components:

Internal Assessment Marks by the Project/Dissertation Guide	:	25 marks
Evaluation of Project/Dissertation Report jointly by the External Examiner and the Guide	:	50 marks
Conduct of Viva-Voce Examination jointly by the External Examiner and the Guide	:	25 marks

Syllabus for Elective Papers

(For Candidates admitted during 2019 - 2020 and onwards)

17S13EA	Object Oriented Programming with C++	Elective 1

Unit I

Principles of Object – Oriented Programming – Software Evolution Procedure and Object Oriented Paradigm – Basic concepts of Object – Oriented Programming – Benefits of OOP – Object Oriented Languages – Application of OOP - Beginning with C++ - What is C++?. - Application of C++ - C++ statements – Structure of C++ Program – Tokens , Expressions and Control Structures – Tokens – Identifiers – Basic and User – Defined Data Types – Operators in C++ - Operator Overloading – Operator precedence – Control Structures.

Unit II

Functions in C++:- The Main Function – Function Prototyping – Call by Reference – Return by Reference – Inline functions – Function Overloading – Friend and Virtual Functions – Classes and Objects – Introduction – Specifying a Class – Defining Member function – Nesting of Member Function – Private member Functions – Arrays within a Class – Static Data Members-Static Member Function – Array of Objects – Objects as Function Arguments, Friendly Functions – Pointers to Members.

Unit III

Constructors and Destructors:– Constructors – Copy Constructor Dynamic Constructor-Constructing Two – Dimensional Arrays – Destructors – Operators Overloading – Type Conversions.

Unit IV

Inheritance, Extending Classes:– Defining Derived classes – Single, Multilevel, Multiple, Hierarchical and Hybrid inheritance – Virtual Base Classes – Abstract Classes-Pointers, Virtual Functions and Polymorphism – Pointers to Derived Classes – Virtual Functions.

Unit V

Managing Console I/O Operations:–C++ streams – C++ stream Classes – Unformatted I/O Operations - Formatted Console I/O Operations – Managing output with Manipulators- Working with Files:– Classes for File Stream Operations- Opening and Closing a File - File Pointers and their manipulators – sequential I/O Operations. Simple Statistical Problems.

Books for Study and Reference

1. Balagurusamy, E. (1998). Object Oriented Programming with C++, Tata McGraw Hill Publishing Company Limited, New Delhi.
2. Somashekar, M. T., Guru, D. S., Negendraswamy, H. S., and Manjunatha, K. S. (2012). Object Oriented Programming with C++, Prentice Hall Learning (India) Private Limited.
3. Venugopal, K. R., Rajkumar, B., and Ravi Shankar, T. (1999). Mastering C++, Tata McGraw – Hill, New Delhi.

17S13EB	Official Statistics	Elective 2

Unit I

Statistical System in India: Central and State Government Organizations, Functions of Central Statistical Organization (CSO), National Sample Survey Organization (NSSO). Organization of large scale sample surveys. General and special data dissemination systems.

Unit II

Official statistics: Meaning, methods of collection, limitations and reliability. Principal publications containing data on the topics such as population, agriculture, industry, trade, prices, labour and employment, transport and communications - Banking and finance.

Unit III

System of Collection of Agricultural Statistics - Crop forecasting and estimation - Productivity, fragmentation of holdings - Support prices - Buffer stocks - Impact of irrigation projects**.** Statistics related to industries, foreign trade - Balance of payment - Inflation - Social statistics.

Unit IV

Index Numbers: Price, Quantity and Value indices. Price Index Numbers: Construction, Uses, Limitations, Tests for index numbers, Chain Index Number. Consumer Price Index, Wholesale Price Index and Index of Industrial Production – Construction of index numbers and uses.

Unit V

National Income – Measures of national income - Income, expenditure and production approaches - Applications in various sectors in India. Measurement of income inequality: Gini's coefficient, Lorenz curves, Application of Pareto and Lognormal as income distribution.

Books for Study and Reference

1. Allen R. G. D. (1975). Index Numbers in Theory and Practice, Macmillan.

2. Bhaduri, A. (1990). Macroeconomics: The Dynamics of Commodity Production, Macmillan India Limited, New Delhi.

3. Branson, W. H. (1992). Macroeconomic Theory and Policy, Third Edition, Harper Collins Publishers India (P) Ltd., New Delhi.

4. C. S. O. (1990). Basic Statistics Relating to the Indian Economy.

5. C.S.O. (1995). Statistical System in India.

6. C. S. O. (1999). Guide to Official Statistics.

7. Goon A. M., Gupta M. K., and Dasgupta. B. (2001), Fundamentals of Statistics, Vol. 2, World Press, India.

8. Mukhopadhyay, P. (2011). Applied Statistics, Second Edition, Books & Allied Ltd, India.

9. Panse, V. G. (1964). Estimation of Crop Yields (FAO), Food and Agriculture Organization of the United Nations.

17S13EC	Computer Simulation and Modeling	Elective 3

Unit I

Introduction to Simulation: Advantages and Disadvantages of Simulation - Areas of Application - System environment - Components of a system - Types of models - Discrete-event system simulation - Steps in a Simulation Study – Examples for simulation - Programming Languages for simulation: FORTRAN, GPSS, SIMAN, SIMSCRIPT, SLAM and MODSIM III.

Unit II

Statistical Models in Simulation: Discrete and continuous probability distributions – Poisson, uniform, exponential, triangular, gamma and normal distributions. Empirical continuous distributions Simulation of Manufacturing and Material Handling System: Modeling of manufacturing system - Issues in Simulating Manufacturing and Material Handling system - Simulations and Languages for Manufacturing and Material handling system.

Unit III

Random number generation: Properties of random numbers - Generation of pseudo-random numbers - Techniques for generating random numbers: Inverse transformation techniques.

Unit IV

Input data analysis: Data collection – Identification of distribution with data - Parameter estimation - Goodness-of fit tests - Chi-square test - Kolmogorov - Smirnov test - Selecting input models without Data. Model Building: Verification and validation - Verification of simulation models - Calibration and validation of models: Face validity - Validation of model assumptions.

Unit V

Output data analysis: Stochastic Nature of Output Data - Types of simulation with respect their estimation - Output analysis for terminating simulation - Output analysis for steady-state simulations. Comparison and evaluation of alternative system designs. Comparison of two system designs - Comparison of several systems designs - Statistical models for estimating the effect of design alternatives – Metamodeling.

Books for Study and Reference

1. Deo, N. (1983): System Simulation with Digital Computer. Prentice Hall of India (Digitized 2007)
2. Gardon, G. (1992): System Simulation (Second Edition). Prentice Hall of India.
3. Jerry Banks, John S. Carson, II and Barry L. Nelson. (1995). Discrete - Event System Simulation (Second Edition). Prentice Hall.
4. Law, A.M. (2007). Simulation Modeling and Analysis (Fourth Edition). McGraw Hill Education.

17S13ED	Data Mining	Elective 4

Unit I

Introduction – An expanding universe of data – production factor – data mining – data mining verses query tools – data mining in marketing – practical applications. Learning: Introduction – self learning – machine learning and methodology of science – concept learning.

Unit II

Data mining and the data warehouses: Introduction – need – decision support system – integration with data mining – client / server data warehousing – multi processing machine – cost justification.

Unit III

Knowledge discovery process: Introduction – data selection – cleaning – enrichment – coding – data mining and its techniques – reporting.

Unit IV

KDD environment: Introduction – different forms of knowledge – getting started – data selection – cleaning – enrichment – coding – reporting - ten golden rules.

Unit V

Customer profiling – predicting bid behavior of pilots – learning of compression of data sets – noise and redundancy – fuzzy database – the traditional theory – relation to tables – statistical dependencies – data mining primitives.

Books for Study and References

1. Adriaans, P., and Zantinge, D. (1996). Data Mining, First Edition, Addison Wesley Professional, London
2. Soman, K. P., Diwakar, S., and Ajay, V. (2006). Data Mining: Theory and Practice, PHI Learning Pvt. Ltd., New Delhi.
3. Delmater, R., and Hancock, M. (2001). Data Mining Explained, Digital Press, MA..
4. Hand, D., Mannila, H., and Smyth, P. (2001). Principles of Data Mining, MIT Press, London.

17S13EE	Applied Regression Analysis	Elective 5

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 Study and Reference

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, John Wiley & Sons, NY.
3. Hosmer, D.W., Lemeshow, S., and Sturdivant, R. X. (2013). Applied Logistic Regression,Third Edition, John Wiley & Sons, NY.
4. Seber, G.E.F. and Wild, C.J. (2003). Nonlinear Regression, John Wiley & Sons, NY.
5. Neter, J., Wasserman, W., and Kutner, M.H. (1989). Applied Linear Statistical Models, Second Edition, Irwin, IL.