DEPARTMENT OF STATISTICS
SCHOOL OF MATHEMATICAL SCIENCES
KAVAYITRI BAHINABAI CHAUDHARI
NORTH MAHARASHTRA UNIVERSITY
JALGAON - 425001, INDIA

SYLLABUS

FOR

M.Sc. STATISTICS
(Semester I to IV)
With specialization in Industrial Statistics
(Medium of Instructions: English)

WITH EFFECT FROM
ACADEMIC YEAR
2019-2020

Summary of Distribution of Credits under CBCS Scheme
for
M.Sc. (Statistics)
with specialization in Industrial Statistics
at
School of Mathematical Sciences
[at University Campus under Academic Flexibility w.e.f. 2019-20]

Sr. No.	Course Type	Sem I	Sem II	Sem III	Sem IV	Total
01	Core	16	16	16	12	60
02	Skill Based	04	04	--	--	08
03	Program Elective	--	--	04	04	08
04	Audit	02	02	02	02	08
05	Project	--	--	--	04	04
06	Practical	03	03	03	03	12
	Total Credits	**25**	**25**	**25**	**25**	**100**

Subject Type	Core	Skill based	Program Elective	Audit	Project	Practical	Total
Credits	60	08	08	08	04	12	100

Total Credits = 100

KAVAYITRI BAHINABAI CHAUDHARI
NORTH MAHARASHTRA UNIVERSITY, JALGAON
Syllabus for M.Sc. (Statistics)
With specialization in Industrial Statistics

(With effect from Academic Year 2019-20)

Syllabus Structure under revised CBCS for PG courses in the University Campus

Semester-I

Course Type	Course Code	Title of the Course	Contact hours/week			Distribution of Marks for Examination						Credits
						Internal		External		Total		
			Th(L)	Pr	Total	Th	Pr	Th	Pr	Th	Pr	
Core	ST-101	Real Analysis	04	--	04	40	--	60	--	100	--	04
Core	ST-102	Linear Algebra	04	--	04	40	--	60	--	100	--	04
Core	ST-103	Sampling Theory and Statistics for National Development	04	--	04	40	--	60	--	100	--	04
Core	ST-104	Distribution Theory	04	--	04	40	--	60	--	100	--	04
Skill Based	ST-105	R Programming and Numerical Methods	04	--	04	40	--	60	--	100	--	04
Practical	ST-106	Practicals- I	--	06	06	--	40	--	60	--	100	03
Audit Course	AC-101	Practicing Cleanliness	02		02	100		--	--	100		02

Semester-II

Course Type	Course Code	Title of the Course	Contact hours/week			Distribution of Marks for Examination						Credits
						Internal		External		Total		
			Th(L)	Pr	Total	Th	Pr	Th	Pr	Th	Pr	
Core	ST-201	Probability Theory	04	--	04	40	--	60	--	100	--	04
Core	ST-202	Linear Models and Regression Analysis	04	--	04	40	--	60	--	100	--	04
Core	ST-203	Multivariate Analysis	04	--	04	40	--	60	--	100	--	04
Core	ST-204	Parametric Inference	04	--	04	40	--	60	--	100	--	04
Skill Based	ST-205	Python Programming	04	--	04	40	--	60	--	100	--	04
Practical	ST-206	Practicals-II	--	06	06	--	40	--	60	--	100	03
Elective Audit Course	AC-201(A)	Soft Skills	02		02	100		--	--	100		02
	AC-201(B)	Practicing Sports Activities										
	AC-201(C)	Practicing Yoga										
	AC-201(D)	Introduction to Indian Music										

Semester-III

Course Type	Course Code	Title of the Course	Contact hours/week			Distribution of Marks for Examination						Credits
						Internal		External		Total		
			Th(L)	Pr	Total	Th	Pr	Th	Pr	Th	Pr	
Core	ST-301	Asymptotic and Nonparametric Inference	04	--	04	40	--	60	--	100	--	04
Core	ST-302	Design, Planning and Analysis of Experiments	04	--	04	40	--	60	--	100	--	04
Core	ST-303	Total Quality Management (TQM) and Statistical Process Control (SPC) and Reliability	04	--	04	40	--	60	--	100	--	04
Core	ST-304	Stochastic Processes	04	--	04	40	--	60	--	100	--	04
Elective	ST-305(A)	Design and Analysis of Clinical Trials	04	--	04	40	--	60	--	100	--	04
	ST-305(B)	Econometrics										
Practical	ST-306	Practicals-III	--	06	06	--	40	--	60	--	100	03
Elective Audit Course	AC-301(A)	Computer Skills	02		02	100		--	--	100		02
	AC-301(B)	Cyber Security										
	AC-301(C)	Base Statistical Analysis Software (SAS)										
	AC-301(D)	Review of Research Paper										

Semester-IV

Course Type	Course Code	Title of the Course	Contact hours/week			Distribution of Marks for Examination						Credits
						Internal		External		Total		
			Th(L)	Pr	Total	Th	Pr	Th	Pr	Th	Pr	
Core	ST-401	Optimization Techniques	04	--	04	40	--	60	--	100	--	04
Core	ST-402	Actuarial Statistics	04	--	04	40	--	60	--	100	--	04
Core	ST-403	Time Series Analysis	04	--	04	40	--	60	--	100	--	04
Elective	ST-404(A)	Data Mining	04	--	04	40	--	60	--	100	--	04
	ST-404(B)	Survival Analysis										
Practical	ST-405	Technical Communications and Practicals-IV	--	06	06	40	--	60	--	100	--	03
Project	ST-406	Project	--	08	08	--	40	--	60	--	100	04
Elective Audit Course	AC-401(A)	Human Rights	02		02	100		--	--	100		02
	AC-401(B)	Current Affairs										
	AC-401(C)	Introduction to LaTeX										
	AC-401(D)	History of Statistics										

Program at a Glance

Name of the program (Degree)	: M. Sc. (Statistics)
Faculty	: Science and Technology
Duration of the Program	: Two years (four semesters)
Medium of Instruction and Examination	: English
Exam Pattern	: 60 : 40 (60 marks University exam and 40 marks continuous internal departmental exam/ assessment)
Passing standards	: 40% in each exam separately (separate head of passing)
Evaluation mode	: CGPA
Total Credits of the program	: 100

Program Objectives for M.Sc. Program:

1. To impart the profound theoretical and practical knowledge of the specific science discipline along with the fundamental core concepts
2. To train the students to employ modern techniques, tools, methodologies, equipment, hardware/software etc. to perform objective oriented scientific and planned experiments
3. To groom the students for all-round development and mould them in a trained workforce to provide teaching-learning, research, business, professional supports in the various science disciplines
4. To make the student to develop the ability to think analytically, independently and draw logical conclusions to solve real-life problems.
5. To utilize the skills and knowledge gained through the subject to deal with real life situations and problems related to society, environment, research and development etc.

Program Outcomes (PO) for M.Sc. Program:

Upon successful completion of the M.Sc. program, student will be able to:

PO No.	Program Outcomes	Cognitive level
PO1	Understand the basic concepts, fundamental principles, and the scientific theories related to various scientific phenomena and their relevancies in the day-to-day life.	2
PO2	Administer the skills in handling scientific instruments, planning and performing in laboratory experiments	3
PO3	Analyse the given scientific experimental data critically and systematically and the ability to draw the objective conclusions.	4
PO4	Develop various skills such as communication, managerial, leadership, entrepreneurship, teamwork, social, research etc., which will help in expressing ideas and views clearly and effectively	3
PO5	Model and formulate the real problems and find solution based-on knowledge acquired	6
PO6	To evaluate how developments in any science subject helps in the development of other science subjects and vice-versa and how interdisciplinary approach helps in providing better solutions and new ideas for the sustainable developments.	5

Program Specific Objectives (PSOs): M.Sc. Statistics

Through this degree program

1. Students are expected to learn mathematical methods for Statistics, Mathematical Statistics, core Statistical Methods as per the syllabi provided by UGC and as per the syllabus for NET/SET/GATE and MPSC/UPSC examinations.
2. Students are expected to learn in depth the computational Statistical tools through computer programming and Statistical software.
3. Technical communications and other audit courses will develop overall personality of student.
4. Students will be trained through the projects to handle real life statistical situations and tackle working challenges before statisticians.
5. After the completion of this M.Sc.(Statistics) degree program candidates will be ready to serve in:
   i) Industry (Banking, Finance, Insurance, Production, Software, etc)
   ii) Government organizations
   iii) Teaching and research

Program Specific Outcomes for M. Sc. Statistics

After completion of the M. Sc. Statistics program, the students should be able to:

Program Specific Outcome (PSO) No.	Program Specific Outcome	Cognitive Level
PSO1	Understand basic concepts of Mathematical methods, Probability theory and Statistical Inference	2
PSO2	Explain different statistical methods with in dept theoretical knowledge and their practical applications	3
PSO3	Analyze different data sets related to sample surveys, Design of Experiments, Statistical process control etc. by using statistical software and computer programming.	4
PS04	Able to convert real life problems from different fields in statistical manner and offer solutions for such problems.	4
PS05	Able to prepare statistical reports and present before committees.	2

Detail Syllabus

ST-101: REAL ANALYSIS

Course Objectives (CObs):

- To learn the concepts of basic topological objects such as open sets, closed sets, compact sets
- To understand the concept of convergence of sequence, series, functions and sequences of functions
- To work comfortably with continuous, differentiable and Riemann integrable functions.

- **The Real Number System: (8 Marks)**
  - Introduction, The field axioms, the order axioms, Geometric representation of real numbers, Intervals, Integers, The unique factorization theorem for integers. (2L)
  - Rational numbers, Irrational numbers, Upper bounds, Lower bounds, Least upper bound, Greatest lower bound of the sets of real numbers. (2L)
  - The completeness axiom, some properties of the supremum and infimum, Archimedean property of the real number system. (2L)
  - Rational numbers with finite decimal representation, Finite decimal approximations to real numbers, Infinite decimal representation of real numbers. (1L)
  - Absolute values and the triangle inequality, The Cauchy-Schwarz inequality, Plus and minus infinity and the extended real number system R^*. (1L)

- **Basic Notions of Set Theory: (6 Marks)**
  - Ordered pairs, Cartesian product of two sets, Relations and functions. Further terminology concerning functions, One-to-one functions and inverses, Composite functions. (2L)
  - Similar (equinumerous) sets, Finite and infinite sets, Countable and uncountable sets, Uncountability of real number system. (2L)
  - Set algebra, countable collections of countable sets and related results. (2L)

- **Elements of Point Set Topology: (5 Marks)**
  - Introduction to n-dimensional Euclidean space, Open and closed intervals, Open and closed sets on the real line, limit points of a set, Compact set. (2L)
  - Bolzano-Weierstrass theorem, Heine-Borel theorem for real line R (without proof). (1L)

- **Sequences and Series of Real Numbers: (15 Marks)**
  - Introduction and examples of sequences of real number. (1L)
  - Convergence of sequences, limit of a sequence, limit superior and limit inferior of a real-valued sequences, Monotone sequences of real numbers. (2L)
  - Cauchy sequences and related results. (2L)
  - Infinite series, Alternating series. (1L)
  - Convergence of Series, Absolute and conditional convergence. (1L)
  - Comparison test and limit comparison test (1L)
  - The power series and its convergence, Cauchy Hadmard Theo.(without proof) (1L)
  - Ratio test and Root test, Cauchy integral test, Dirichlet's test, Abel's test. (4L)

- **Limit and Continuity: (6 Marks)**
  - Limits of functions. (1L)

- Continuous functions. (1L)
- Uniform continuity. (1L)
- Discontinuities. (1L)
- Continuity and compactness. (2L)
- Monotone function and discontinuities. (1L)

- **Sequences of Functions: (6 Marks)**
  - Introduction and examples of sequences of real-valued functions. (1L)
  - Pointwise convergence of sequences of functions. (1L)
  - Definition of uniform convergence, Uniform convergence and continuity. (2L)
  - Power series and radius of convergence. (1L)

- **Differentiation and functions of several variables. (6 Marks)**
  - Derivative of a Real Function. (1L)
  - Maxima-minima of function, Mean value theorems. (2L)
  - Continuity and Derivatives. (1L)
  - Derivatives of higher order, Taylor's theorem (without proof). (1L)
  - Functions of several variables, constrained maxima-minima functions. (2L)

- **Integrals: (8 Marks)**
  - Riemann and Riemann- Stieltjes integrals, integration by parts, mean value theorem. (3L)
  - Multiple integrals and their evaluation by repeated integration. (2L)
  - Change of variables in multiple integration. (2L)
  - Improper Riemann – Stieltjes integrals: Improper integrals of first and second kind for one variable, uniform convergence of improper integrals. (2L)
  - Differentiation under the sign of integral Leibnitz rule. (2L)

REFERENCES

1. Apostol, T. M. (1985). Mathematical Analysis, (Narosa, Indian Ed.).
2. Courant, R. and John, F. (1965). Introduction to Calculus and Analysis, (Wiley).
3. Miller, K. S. (1957). Advanced Real Calculus, (Harper, New York).
4. Rudin, Walter (1976). Principles of Mathematical Analysis, (McGraw Hill).
5. Malik, S. C. (2005). Principles of Real Analysis, (New Age Inter-national (P) Ltd.).
6. Bartle, R. G. (1976). Elements of Real Analysis, (Wiley).

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST101.1	Identify Sequence and Series comprising convergence sequences and their upper and lower limits.	2
ST101.2	Evaluate the limits of functions, infinite limits and limit at infinity.	4
ST101.3	Understand the Continuity, Mean value theorem and Taylor's theorem.	2

ST-102: LINEAR ALGEBRA

Course Objectives (CObs):

- To understand the vector spaces and subspaces and important concepts of vector spaces such as independence, basis, dimensions, orthogonality etc.
- To understand the link between linear transformation, its properties and matrices, matrix-operations; the spaces associated with matrices and interrelation between them, rank-factorization, eigen and spectral analysis of a matrix.
- To determine the existence and uniqueness of the solution of a linear system of equations, solution set and determining all possible solutions using generalized inverse, Quadratic forms and their definiteness categories, maxima/minima etc

- **Preliminaries: (2 Marks)**
  - Binary operations, Groups, Polynomials. (2L)

- **Vector Spaces (VS) : (12 Marks)**
  - Definition of VS, Subspaces, Linear span of set (3L)
  - Linear span of a set, Span of a set as a smallest subspace containing the set, Generating set of VS, Results on span of a set. (2L)
  - Intersection and union of subspaces, Completion theorem. (2L)
  - Linear dependence and linear independence of set of vectors, Necessary and sufficient condition for linear dependence of set of vectors. (2L)
  - Steinitz exchange theorem, Maximal linearly independent set, minimal generating sets. (2L)
  - Basis of VS, Dimension, Extension of linearly independent set to a basis (algorithm and theorem), relation between dimensions of subspaces; one of which is subset of other. (4L)
  - Sum of two sets, modular law. (1L)

- **Algebra of Matrices: (12 Marks)**
  - Linear transformations and matrices, Addition, Scalar multiple and composition of linear transformation, The corresponding operations on matrices, Elementary properties of matrix operations, Upper and lower triangular matrices, Trace of a matrix and related results. (3L)
  - Row and column spaces, Rank of a matrix, Left inverse, Right inverse and inverse of a matrix, properties of inverse, Upper bound for rank of product of matrices, Rank cancellation laws. (2L)
  - Rank factorization theorem, properties of idempotent matrix (1L)
  - Nullity of matrix, null space of a matrix, rank of null space of a matrix with rank of a matrix. (2L)
  - Lower bound for rank of product of two matrices, Rank of sum of matrices. (1L)
  - Partitioned matrix, Elementary matrix, Determinant of a matrix, Its elementary properties, Determinant and inverse of partitioned matrix, Kronecker product. (3L)

- **Systems of Linear Equations: (8 Marks)**
  - Consistent and inconsistent system of equations, Homogeneous systems and existence of nontrivial solution, General linear systems, Solution of systems of equations. (3L)

- Generalized inverse of a matrix and its properties, Moore-Penrose generalized inverse, Solution of systems of equations. (3L)

- **Inner Product and Orthogonality: (10 Marks)**
  - VS with inner product, Normed vector spaces, Cauchy-Schawrz inequality, Orthogonality and linear independence. (2L)
  - Orthonormal basis, Expression of any vector in VS as a linear combination of elements of orthonomal basis. (2L)
  - Gram-Schmidt orthogonalization process, Extension of any orthogonal set to orthonormal basis of VS, Examples. (2L)
  - Orthogonal and unitary matrices and their properties. (2L)

- **Eigen Values: (8 Marks)**
  - Characteristic polynomial and characteristic equation of a matrix, Characteristic roots, their properties. (2L)
  - Eigen values and eigen vectors, Eigenspaces, Geometric and algebraic multiplicity of an eigen value, Relation between the 2 multiplicities, Simple and regular eigen values, Properties of eigen values. (3L)
  - Cayley-Homilton theorem and minimal polynomial, Singular values and singular vectors. (2L)
  - Spectral decomposition of real symmetric matrix, singular value decomposition, Jordan decomposition. (2L)

- **Quadratic Forms (QF): (8 Marks)**
  - Real QF, Classification, Rank and signature, reduction of any QF to diagonal form. (2L)
  - Definiteness of a matrix, equivalence of nonnegative definite matrix and variance-covariance matrix, Simultaneous reduction of two QF. (3L)
  - Extrema of QF, Maxima and Minima of ratio of two QF. (2L)

REFERENCES

1. Graybill, F.A.(1983). Matrices with Applications in Statistics (2nd Ed. Wadsworth)
2. Rao, A.R. and Bhimasankaram, P. (2000). Linear Algebra. (Hindustan Book Agency).
3. Rao, C.R. (2002). Linear Statistical Inference and its Applications. (2nd ed. John Wiley and Sons)
4. Searle, S. R. (1982). Matrix Algebra Useful for Statistics. (John Wiley and Sons Inc.).
5. Bellman, R.(1970). Introduction to Matrix Analysis, (2nd ed.Tata McGraw Hill).
6. Biswas, S.(1984). Topics in Algebra of Matrices, (Academic Publictions).
7. Hadley, G.(1987). Linear Algebra, (Narosa Publishing House).
8. Halmos, P.R.(1958). Finite-dimensional Vector Spaces, (2nd ed. D.Van Nostrand Company, Inc.).
9. Hoffman, K. and Kunze, R. (1971). Linear Algebra, (2nd Ed.Prentice Hall, Inc.)
10. Rao, C.R. and Mitra, S.K. (1971). Generlized Inverse of Matrices and its Applications, (John Wiley and Sons Inc.).

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST102.1	Understand the concept of linear independence, bases and dimension associated with vector spaces, dimensionality theorem etc.	2
ST102.2	Determine existence of left, right and proper inverses, rank inequalities under matrix operations, different factorizations and decompositions of a matrix, solve linear systems etc	3
ST102.3	Construct the orthogonal matrix associated with a non-singular matrix through a Gram-Schmidth orthogonalization process, diagonalization of a symmetric matrix, the role of eigenvalues, eigenvectors, Cayley Hamilton theorem in theory of matrices etc.	3

ST-103: SAMPLING THEORY AND STATISTICS FOR NATIONAL DEVELOPMENT

Course Objectives (CObs):

- To provide knowledge and training of sample surveys, methods of estimations of population parameters under different sampling schemes.
- To make students aware of National Economy and National Indicators of Economy and teach them role of statistics in National Developments.

- **Sample Surveys:**
  - **Preliminaries: (6 Marks)**
    - Objectives of sample survey, planning for sample survey. (1L)
    - Basic issue related to estimation [biased and unbiased estimator, mean square error (MSE)] and confidence interval (2L)
    - Concept of sampling distribution of statistic (2L)
    - Sampling and non-sampling errors (1L)

  - **Review of basic methods of sample selection from finite population. (10 Marks)**
    - Simple random sampling with replacement, Simple random sampling without replacement, Systematic sampling and related results on estimation of population total, mean and proportion. (5L)
    - Stratified sampling: Formation of strata and number of strata, Allocation problems and estimation problems. (5L)

  - **Unequal Probability Sampling Designs: (8 Marks)**
    - Inclusion probabilities, Horwitz-Thompson estimator and its properties. (3L)

- PPSWR, PPSWOR methods (including Lahiri's scheme) and related estimators of a finite population mean (Heansen-Horwitz and Desraj estimators for a general sample size and Murthy's estimator for a sample of size 2). (5L)
- Midzuno sampling design, πps design. (3L)

- Use of supplementary information for estimation, Ratio and Regression estimators based on SRSWOR method of sampling, Their properties and MSEs. (5 Marks,5L)
- The Jackknife technique. (2 Marks,2L)
- Cluster sampling, Estimator of population mean and its properties. (4 Marks,3L)
- Two-stage sampling with equal number of second stage units. (2 Marks,2L)
- Double sampling and its uses in ratio and regression estimation. (3 Marks,3L)
- Randomized response technique, Warner's model; related and unrelated questionnaire methods. (4 Marks, 3L)

- **Statistics for National Development:**
  - **Economic Development: (6 Marks)**
    - Growth in per capita income and distributive justice. (1L)
    - Indices of development. (1L)
    - Human Development indexes. (1L)
    - Estimation of national income-product approach, income approach and expenditure approach. (2L)
  - Population growth in developing and developed countries, Population projection using Leslie matrix, Labour force projection. (2 Marks, 2L)
  - Measuring inequality in incomes, Lorenz curve, Gini coefficient, Theil's measure. (2 Marks, 2L)
  - **Poverty measurement: (6 Marks)**
    - Different issues related to poverty. (2L)
    - Measures of incidence and intensity. (2L)
    - Combined measures e.g. Indices due to Kakwani, Sen etc. (2L)

REFERENCES

Sampling Methods:

1. Cochran, W.G. (1984). Sampling Techniques, (Wiley).
2. Des Raj and Chandok (1999). Sample Survey Theory, (Narosa).
3. Sukhatme, P.V, Sukhatme, B.V and Ashok C. (1984). Sampling Theory of Surveys with Applications, (Iowa State University Press & IARS).
4. Mukhopadhay P. (2002). Theory and Method of Sample Survey, (Chapman and Hall)

Statistics for National Development:

1. CSO. National Accounts Statistics- Sources and Health.
2. Sen, A. (1997). Poverty and Inequality.
3. Datt R., Sundharam, K. P. M. (Revised edition). Indian Economy, (Sultan Chand & company Ltd.)

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST103.1	Describe different methods of sampling survey methods and objectives and give examples of situations where these methods are useful.	2
ST103.2	Compute different selection or inclusion probabilities under various sampling schemes.	3
ST103.3	Analyse survey data by using estimation procedures under different sampling methods.	4
ST103.4	Describe estimation of population parameters under different sampling methods.	2
ST103.5	Explain different economic indicators and role of statistics in National Developments.	2

ST-104: DISTRIBUTION THEORY

Course Objectives (CObs):

- To demonstrate an understanding of the basic concepts on probability and random variables
- To formulate mathematical concepts on probability and probability distributions with practical applications.
- To determine marginal and conditional distributions from bivariate distributions. And to study related properties such as independence etc.
- To study functions of random variables and to determine their distributions using various techniques. To study general theory of sampling distributions of statistics and order statistics.

- **Brief review of basic distribution theory: (5 Marks)**
  - Random experiment and its sample space, events. (1L)
  - Probability axioms. (1L)
  - Random variables, Discrete random variables, Continuous random variables. (1L)
  - P.d.f., p.m.f., c.d.f. of random variables. (1L)
  - M.g.f., p.g.f., c.g.f., characteristic function of random variables. (1L)
  - Moments: raw moments, Central moments, Factorial moments. (1L)
- **Standard discrete and continuous distributions: (8 Marks)**
  - Bernoulli, Binomial, Geometric, Negative Binomial, Poisson, Hypergeometric distributions. (2L)
  - Exponential, Normal, Gamma, Beta, Uniform, Chi-square, Lognormal, Weibull, Cauchy distributions. (2L)

- M.g.f, p.g.f., c.g.f., characteristic function, Moments of above distributions. (2L)
- Properties of above distributions. (2L)

- **Joint, Marginal and Conditional distributions: (10 Marks)**
  - Concept of random vectors, Joint, Marginal and conditional distributions Variance-covariance matrix. (1L)
  - Joint p.m.f. of discrete random variables, Joint p.d.f. of continuous random variables.(1L)
  - Marginal and conditional density using joint density. (1L)
  - Conditional expectation and variance. (1L)
  - Independence of random variables. (1L)
  - Bivariate normal distribution; Joint p.d.f. Marginal p.d.f.s, Conditional p.d.f., Joint m.g.f., Some properties. (2L)
  - Bivariate exponential distribution: joint p.d.f., Marginal p.d.f.s, properties. (1L)
  - Multivariate normal distribution: joint p.d.f., Marginal p.d.f., Conditional p.d.f., Joint m.g.f. (2L)
  - Multinomial distribution: joint p.m.f., Marginal p.m.f., Conditional p.m.f., Joint m.g.f. (2L)

- **Functions of random variables and their distributions: (10 Marks)**
  - Function of random variables. (1L)
  - Joint density of functions of random variables using Jacobian of transformation. (3L)
  - Convolution of random variables. (1L)

- **Compound, Truncated and Mixture Distributions: (3 Marks)**
  - Concept, applications, examples and problems. (3L)

- **Correlation: (3 Marks)**
  - Multiple and Partial Correlation. (2L)

- **Sampling Distributions: (6 Marks)**
  - Sampling distribution of statistics from univariate normal random samples. (2L)
  - Non-central Chi-square, t and F-distributions and their properties. (5L)

- **Quadratic forms under Normality: (6 Marks)**
  - Distribution of linear and quadratic forms in i.i.d. Standard normal variables (Technique based on m.g.f.). (2L)
  - Independence of two linear forms, Independence of two quadratic forms and independence of linear form and quadratic form. (2L)
  - Fisher Cochran's theorem. (2L)
- **Order Statistics: (9 Marks)**
  - Distribution of r^{th} order statistics, Joint distribution of several order statistics and their functions. (4L)
  - Distribution of function of order statistics. (2L)
  - Extreme values and their asymptotic distributions (statement only) with applications. (2L)
  - Distribution of spacings, normalized spacings with illustration to exponential case. (3L)

REFERENCES

1. Rohatgi V.K. and Ehsanes Saleh A. K. MD. (2003). An Introduction to Probability Theory and Mathematical Statistics, (Wiley Eastern, 2nd Ed.).
2. Hogg, R.V. and Craig, A.T. (1978). Introduction to Mathematical Statistics, (5th Ed. Pearsons Education).
3. Hogg, R.V. and Tanis E.(2002) An. Probability and Statistical Inference (6th Ed. Pearsons Education).
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6. Pitman, J. (1993). Probability, (Narosa Publishing House).
7. Johnson, S. and Kotz, (1972). Distributions in Statistics, (Vol..I, II and III, Houghton and Miffin).
8. Cramer H. (1946). Mathematical Methods of Statistics, (Princeton).
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10. David, Herbert Aron, and Haikady Navada Nagaraja. "Order statistics." *Encyclopedia of Statistical Sciences* (2004).
11. Johnson, Norman Lloyd, Samuel Kotz, and Narayanaswamy Balakrishnan. "Continuous univariate distributions." *Journal of the Royal Statistical Society-Series A Statistics in Society* 159.2 (1996): 343.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST104.1	Develop problem-solving technique to real-world events. Identify the features that describes a distribution of data.	3
ST104.2	Understand various discrete and continuous probability distributions along with their real-life applications. Interrelation between probability distribution of random variables and decomposition of mixture distributions.	2
ST104.3	Understand transformation of random variables concept and related procedures to obtain their distributions. Learn compounding and truncation technique to generate new distributions.	2
ST104.4	Apply general distribution theory of order statistics.	3

ST-105: R PROGRAMMING AND NUMERICAL METHODS

Course Objectives (CObs):

- To review the core topics in probability and statistics through the study and practice of data analysis and graphical interpretation using 'R'.
- Students will learn R-reporting and developing own R code/packages/ Apps.

Unit I (12L, 12M)

- Introduction to R-A programming language and environment for data analysis and graphics.
- Syntax of R expressions: Vectors and assignment, vector arithmetic, generating regular sequence, logical vector, character vectors, Index vectors; selecting and modifying subsets of data set
- Data objects: Basic data objects, matrices, partition of matrices, arrays, lists, factors and ordered factors, creating and using these objects; Functions- Elementary functions and summary functions, applying functions to subsets of data.
- Data frames: Benefits of data frames, creating data frames, combining data frames, Adding new classes of variables to data frames; Data frame attributes.

Unit II (12L, 12M)

- Importing data files: import.data function, read.table function; Exporting data: export.data function, cat, write, and write.table functions; Outputting results - sink function, formatting output - options, and format functions; Exporting graphs - export.graph function.
- Graphics in R: creating graphs using plot function, box plot, histogram, line plot, steam and leaf plot, pie chart, bar chart, multiple plot layout, plot titles, formatting plot axes; 3-D plots: Contour plots, perspective plots, and image plots: Visualizing the multivariate data: Scatter plot matrices, Star plots, Faces
- Interactively adding information of plot - Identifying the plotted points, adding trend lines to current scatter plot, adding new data to current plot, adding text and legend
- Loops and conditional statements: Control Statements; if statement, if else Statement. Looping statement; for loop, repeat, while loop

Unit III (12L, 12M)

- Developing simple programs in R for data analysis tasks, saving programs, executing stored programs, defining a new binary operator, assignment within function, more advanced examples, object oriented programme. Creating function libraries- library function, attaching and detaching the libraries, R packages and data sets.
- Performing data analysis tasks: Reading data with scan function, Exploring data using graphical tools, computing descriptive statistics, one sample tests, two sample tests, Goodness of fit tests, vector and matrix computation, Defining Statistical Models: Introduction for defining models, Generic functions for extracting model information.

Unit IV (6L, 6M)

- Probability and Distributions: Random sampling and combinatory, obtaining density, cumulative density and quantile values for discrete and continuous distributions, generating samples from discrete and continuous distributions, plotting density and

cumulative density curves, Q-Q plot.

Unit V (18L, 18M)

- Errors in Numerical Calculations: Introduction, Errors and their Analysis, general error formula, error in series approximation.
- Iterative methods: Introduction, bisection, Newton-Raphson method for finding roots of polynomial equation.
- Interpolation: Newtons methods, Langrangian method, direct method
- Solution of Simultaneous Algebraic Equations: Introduction, Direct method, Matrix Inversion Method, Jacobi iteration method, Gauss elimination method, Pivoting, Gauss-Seidel iterative method, Gauss Jordan method, Eigen value Problem.
- Numerical Integration: Introduction, Simpson's 1/3 rule, Trapezoidal rule, Quadrature rule, Simpson's 3/8 rule, Errors in integration formulae.

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST105.1	Describe R methods/codes/packages/ Apps in R programming	2
ST105.2	Develop various R Programs for statistical problems, models and methods	3
ST105.3	Construct the different packages and flowcharts useful in Statistics	3

ST-106: PRACTICALS-I

Course Objectives (CObs):

- To understand various statistical tools used in presentation of data.
- Introduce the basic operations and numeric computations in MATLAB software, exercise the understanding of algebraic concepts through computation of inverse, generalized inverse, definiteness; eigen and spectral analysis, orthogonalization of a matrix, etc
- To make students aware of sample survey data and its analysis.
- To generate random samples from various probability distributions

A. Introduction to different Statistical Software Packages (9 Hrs, 6 Marks)

1. Classification, tabulation and frequency tables.
2. Bar graphs, histogram.
3. Stem-and- Leaf plots, Box plots.
4. Summary statistics.
5. Two-way tables and plots.
6. Scatter diagram correlation coefficient.

B. Practicals based on Linear Algebra. (Using software packages) (15 Hours, 10 Marks)

1. Checking linear dependence/independence of set of vectors using system of linear equations.
2. Getting vectors in row/column space and null space of the given matrix.
3. Computation of inverse of a given matrix.
   - Natural inverse.
   - G-inverse, left and right inverse
   - MP-inverse
4. Computing higher order powers of a given matrix using spectral decomposition
5. To obtain rank factorization of given non-null matrix.
6. Gram-Schmidt orthonormalization, forming an orthogonal matrix of specified order using Gram-Schmidt orthogonalization, forming an orthogonal matrix containing a specified vector as a row/column of the matrix.
7. Checking and demonstrating the definiteness of the given matrix, getting vectors from eigen-space, algebraic and geometric multiplicity of an eigen value etc.
8. Demonstration of occurrence of maxima and minima of
   - Quadratic forms over normed vectors.
   - Ratio of two quadratic forms over normed vectors.
9. Verification of Cayley-Hamilton theorem

C. Practicals based on the Sampling Theory and Statistics for National Development. (Using software packages) (30 Hours, 20 Marks)

1. Model Sampling and Estimation
   - Drawing simple random samples from a given finite population using SRSWR and SRSWOR.
   - Estimating the population total, mean and proportion using the sample drawn.
   - Estimating the variance of the estimator obtained above using the sample drawn.
   - Confidence interval for population total, mean and proportion.
   - Comparison of two estimators.

- Minimum sample size requirement.

2. Stratified Random Sampling
   - estimation of population total and mean with S.E.
   - Various kinds of allocations
   - Post stratification.
3. Using Auxiliary Information
   - Ratio method of estimation
   - Regression method of estimation.
4. H-T estimator and PPS, π PS designs
5. Double Sampling.
6. Systematic Sampling
7. Cluster Sampling
8. Two stage sampling
9. Randomized Response Technique
10. Estimation of national income, Income inequality, Poverty measurement.

D. Practical based on Distribution Theory. (Using software packages) (6Hrs , 4 Marks)

1. Generating random samples from discrete, continuous and mixture distributions
2. Fitting of standard distributions and tests for goodness of fit.

E. Practicals based on R Programming and Numerical Methods (30 Hrs, 20 Marks)

1. Install and configuration of R programming environment, Basic language elements and data structures, Data input/output, Data storage formats, Subsetting objects, Functions, Loop functions, Graphics and visualization, Statistical simulation
2. Writing R programs to calculate different summary statistics (mean median, mode, variance, standard deviation, order statistics, range and quantiles) based on the given n observations.
3. R Programs to compute and plot p.m.f.'s and c.d.f.'s of standard probability distributions. (Binomial, Poisson, Geometric, Hyper Geometric, Negative Binomial)
4. Drawing random samples from standard distributions (Binomial, Poisson, Geometric, Exponential, Normal, Gamma, Beta, Discrete, Mixture), preparing frequency distribution of given data.
5. Drawing a random sample of size n using SRSWR and SRSWOR.
6. Calculation of double integrals, limits of functions, computing integrals by statistical methods, computing expectations of complicated functions.
7. Calculation of regression and correlation coefficients, ANOVA for one-way and two way models, Analysis of 2 x 2 contingency table, calculation of p-value for standard normal distribution (for given Z value), box Plot, pie charts, histograms, dot plots, density plots, mean and variance of estimates, calculation of empirical power & level of significance.
8. To locate, install and load R packages, development of personalized functions and R-GUI using R-shiney.
9. Programs based on the numerical methods: Bisection method, Newton-Raphson Method, Numerical Integration by Trapezoidal rule Simpson's rules.

F. Assignment Problem to be solved by students.

1. Preparing frequency distribution of given data.
2. Calculation of p-value for standard Normal distribution (for given Z value)
3. Calculation of regression and correlation coefficients.
4. Sketching p.d.f of the given distribution for various parameters.(Using software)

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST106.1	Use MATLAB to solve algebraic problems, demonstrate and verify various theorems, Lemmas, results and algebraic concepts.	3
ST106.2	Visualize data and exploratory data analysis using statistical software	1
ST106.3	Apply different estimation tools for estimation of population parameters when real life data sets are given.	3
ST106.4	Compare different estimators or sampling methods when real life data sets are given.	4
ST106.5	Simulate random number from from discrete, continuous and mixture distributions with the help of statistical software	3

AUDIT COURSE: SEMESTER-I

AC-101: Practicing Cleanliness

Course Objectives (CObs):

To make students aware of Clean India Mission and inculcate cleanliness practices among them

- Awareness program on
  - Swachh Bharat Abhiyan (Clean India Mission)
  - Clean Campus Mission
  - Role of youth in Clean India Mission
- Cleaning activities inside and surroundings of Department buildings.
- Tree plantation and further care of planted trees
- Waste (Liquid/Solid/e-waste) Management, Japanese 5-S practices
- Planning and execution of collection of Garbage from different sections of University campus
- Role of youth in power saving, pollution control, control of global warming, preservation of ground water and many more issues of national importance.
- Cleanest School/Department and Cleanest Hostel contests
- Painting and Essay writing competitions

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC101.1	Identify need at of cleanliness at home/office and other public places.	2
AC101.2	Plan and observe cleanliness programs at home and other places.	4
AC101.3	Practice Japanese 5-S practices in regular life	3

ST-201: PROBABILITY THEORY

Course Objectives (CObs):

- To teach students the measure theoretical concepts of Probability theory.
- To describe concept of moment inequalities, convergence of sequence of random variables and their applications as WLLN and CLT.

- **Sets and Classes of Events: (6 Marks)**
  - Random experiment, Sample space and events. (1L)
  - Algebra of sets. (1L)
  - Sequence of sets, limit supremum and limit infimum of sequence of sets. (2L)
  - Classes of sets, Sigma-fields (σ-fields), Minimal fields, Minimal σ-field, Parition. (3L)
  - Borel fields in R^1 and R^k, Monotone field. (2L)

- **Random Variables: (6 Marks)**
  - Point function and set function, Inverse function. (2L)
  - Measurable function, Borel function, induced σ-field, Function of a function, Borel function of measurable function. (2L)
  - Real and vector-valued random variable. (2L)
  - σ-field induced by a sequence of random variables. (1L)
  - Limits of Random variable. (2L)

- **Measure and Probability Measure: (6 Marks)**
  - Measure (Definition and simple properties). (1L)
  - Probability measure, Properties of a measure. (1L)
  - Probability space (finite, countable) Continuity of a probability measure. (1L)
  - Extension of probability measure, Caratheodory Extension theorem(without proof) (1L)
  - Probability space induced by r.v. X, Distribution of Borel functions of r.v. (1L)
  - Other measures: Generalized Probability measure, Conditional Probability measure, Counting measure, Lebesgue measure. (2L)

- **Distribution Functions: (6 Marks)**
  - Distribution functions of a r.v. and its properties. (1L)
  - Jordan decomposition theorem, Mixture of distribution functions. (2L)
  - Distribution functions of vector valued r.v.s. (1L)
  - Empirical distribution functions. (1L)

- **Expectation and Moments: (8 Marks)**
  - Integration of measurable function with respect to a measure. (1L)
  - Expectation of a r.v. (Definition for simple, Nonnegative and arbitrary r.v.), Properties of expectation, Expectation of Complex r.v. (3L)
  - Moments, Moment generating function. (1L)
  - Moment inequalities: C_r-inequality, Holder inequality, Schwarz's inequality, Minkowski's inequality, Jensen's inequality, Basic inequality, Markov inequality, Chebyshev's inequality. (3L)

- **Convergence of Sequence of Random variables: (8 Marks)**
  - Convergence in distribution, Convergence in probability, Almost sure convergence and convergence in quadratic mean and their inter-relations. (5L)
  - Monotone convergence theorem, Fatou's Lemma, Dominated convergence theorem. (3L)
- **Characteristic function: (4 Marks)**
  - Definition and simple properties, Some inequalities. (2L)
  - Uniqueness theorem and Levy's continuity thereon (Statements only). (1L)
- **Independence: (5 Marks)**
  - Independence of two events, Independence of n>2 events, sequence of independent events, independent classes of events, independence of r.v.s, Borel zero-one law. (4L)
- **Law of large numbers: (5 Marks)**
  - Weak laws of large numbers (WLLN), Khintchine's WLLN, Kolmogorov's strong law of large number (Statement only) and their applications. (4L)
- **Central limit theorem (CLT): (6 Marks)**
  - CLT for a sequence of independent r.v.s. under Lindeberg's condition, CLT for i.i.d. r.v.s. and its applications. (3L)

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST201.1	Recall and define some more concepts of set theory.	1
ST201.2	Describe field, σ-field, measurable space and measure theoretical definition of random variable.	2
ST201.3	Apply different moment inequalities and concept of convergence of sequence of random variables.	3
ST201.4	Apply WLLN and CLT to solve real life problems.	3

ST-202: LINEAR MODELS AND REGRESSION ANALYSIS

Course Objectives (CObs):

- To provide the theoretical foundation for Linear models.
- To familiar with principles of multiple linear regression and non-linear regression models.
- To study concept of generalized linear models.
- To develop and validate models on the basis of collected data.

- **General Linear Model: (15 Marks)**
  - Gauss-Markov set up, Least square estimation, Normal equations, Consistency of system of normal equations and their solution. (3L)
  - Estimability of linear parametric function, necessary and sufficient condition for estimability, Best Linear Unbiased Estimator (BLUE). (2L)
  - Gauss-Markov theorem, Variances and covariances of BLUE's. (2L)
  - Estimation space, Error space, their ranks, Orthogonality of estimation space and error space. (2L)
  - Simultaneous estimates of linear parametric function, Estimation of error variance, Estimation with correlated observations. (3L)
  - Least square estimates with restriction on parameters, Method of generalized least squares. (3L)

- **Interval Estimation and Test of Hypothesis: (15 Marks)**
  - Under the normality assumption, Distribution of error sum of squares, Regression sum of squares and distribution of BLUE's, their independence. (2L)
  - Distribution of conditional error sum of squares, Distribution of sum of squares due to null hypothesis. (3L)
  - Test of hypothesis for one or more than one estimable linear parametric function, Test of hypothesis of equality of all estimable functions to zero, Testing of sub hypothesis for full rank model, Power of F-test. (3L)
  - Simultaneous confidence interval for n linearly independent estimable parametric functions. (2L)
  - One way and two way classified data, multiple comparison tests due to Tukey-Scheffe. (4L)
- **Regression Analysis: (30 Marks)**
  - Simple and multiple linear regression in Gauss-Markov set up. Estimation of regression coefficients, Regression analysis of variance, Fitted values and residuals. (4L)
  - Polynomial regression, Orthogonal polynomials, Response analysis using orthogonal polynomials. (3L)
  - Residuals and their plots as tests for departure from assumptions such as fitness of the model, Normality, Homogeneity of variances and detection of outliers. (2L)
  - Remedial measures and validation, Multi-collinearity, Ridge regression, Robust regression principal component regression subset selection of explanatory variables, Mallows Cp statistic. (7L)
  - Introduction to non-linear regression models, Least square estimation in non-linear regression, Model building and diagnostics. (4L)

- Generalized Linear model: Link functions required for dependent variable following distributions like Poisson, binomial, inverse binomial, inverse Gaussian, gamma.
  Logistic Regression: Logit transform, ML estimation, Test of hypotheses, Wald test, LR test, score test. (7L)

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST202.1	Apply theory of Linear models to study various statistical techniques such as Regression analysis, Analysis of Variance, Experimental designs etc.	3
ST202.2	Apply various statistical test to determine the acceptability of a fitted model.	3
ST202.3	Construct best fitted model after applying various remedial measures and checking validation of fitted model.	3
ST202.4	Understand the concept of generalized linear models and implementation in real-life situation.	2

ST-203: MULTIVARIATE ANALYSIS

Course Objectives (CObs):

- To understand Multivariate Normal distribution (MVND), its properties, Sampling, Estimation and Hypothesis testing for MVND.
- To learn the sampling distributions, distributions of quadratic forms in MVND and other distributions emerging from MVND.
- To Develop a thorough understanding of multivariate data analysis tools such as Multiple linear regression, Principle component Analysis, Canonical correlations, Discriminant analysis, Cluster and Factor analysis, MANOVA.

- **Introduction to Bivariate Distributions: (4 Marks)**
  - Bivariate normal, Bivariate Poisson, Bivariate Exponential, Bivariate binomial, Bivariate negative binomial. (3L)

- **Multivariate Normal Distribution(MVND): (16 Marks)**
  - Singular and nonsingular MVND, Mean vector and variance covariance matrix. (3L)
  - Characteristic function of MVND. (1L)
  - Additivity property of MVND. (1L)
  - Distribution of linear forms of a vector having MVND, Marginal distributions, Conditional distributions (2L)
  - Necessary and sufficient condition for independence of $\underline{X}^{(1)}$ and $\underline{X}^{(2)}$ (two components of $\underline{X}$). (2L)
  - Central and noncentral χ^2 distribution, their characteristic function, χ distribution. (2L)
  - Distribution of quadratic forms in MVN random vector. (2L)
  - Necessary and sufficient condition for a quadratic form to have χ^2 distribution (1L)
  - Condition for independence of two quadratic forms and its applications, Condition for independence of linear form and quadratic form and its applications. (1L)
  - Random sampling from MVND, Unbiased and maximum likelihood estimators of parameters of MVND, their sampling distributions, independence. (3L)
  - Sample correlation coefficients, their maximum likelihood estimators (mle), Correlation matrix and its mle. (1L)

- **Wishart distribution: (10 Marks)**
  - Wishart matrix, Derivation of Wishart distribution in canonical case and in general case, Bartelett Decomposition theorem. (3L)
  - Characteristic function of Wishart distribution, Additive property of Wishart distribution, Moments of Wishart distribution. (3L)
  - Properties of Wishart distribution. (4L)
  - Necessary and sufficient condition for XAX' to have Wishart distribution and its application. (2L)

- **Hotelling's T^2 and its applications: (10 Marks)**
  - Hotelling's T^2 statistic as a generalization of square of Student's statistic. (1L)
  - Derivation of Hotelling's T^2 statistic from Likelihood Ratio Test, Application of union-intersection principle to obtain Hotelling's T^2 statistic, Invariance of T^2 statistic under scale transformation. (2L)
  - Distance between two populations, Mahalnobis D^2 statistic and its relation with Hotelling's T^2 statistic. (1L)
  - Application of Hotelling's T^2 :
    Test of equality of mean vector for one or more multivariate normal population, Test of equality of components of a mean vector of MVND, Two sample problem. (2L)
  - Rao's U-statistic and its distribution. (1L)

- **Correlation and regression: (4 Marks)**
  - Sample correlation coefficient, its null and non-null distribution, (1L)
  - Regression of X_1 on X_2, ...X_p, properties of residual, multiple correlation coefficient(MCC), m.l.e. of MCC, Null distribution of sample MCC. (2L)
  - Regression of X_1 and X_2 on X_3, ...X_p, residuals, partial correlation coefficient(PCC), sampling distribution of PCC. (1L)

- **Discriminant Analysis: (4 Marks)**
  - Cluster Analysis and classification problem. (2L)
  - Classification and discrimination procedure for discrimination between two multivariate normal populations, sample discriminant function, Probabilities of misclassification and their estimation, Optimum error rate, Test associated with discriminant function. (4L)

- **Principal Components: (4 Marks)**
  - Introduction and need, population principal components, Finding i^{th} principal component, correlation of i^{th} principal component with k^{th}element of vector $\underline{X}$, principal component when Σ has special structure, Sample principal components. (3L)

- **Canonical Correlation: (4 Marks)**
  - Concept of Canonical correlation as generalization of multiple correlation, Geometrical interpretation and its use, Definition of canonical correlation and canonical variables, Existence of canonical variables, Canonical correlation as a maximum root of characteristic equation of a matrix, Sample canonical correlation and canonical variable. (3L)
- **Multivariate Analysis of Variance (MANOVA): (4 Marks)**
  - MANOVA for one way and two ways classified data, Wilk's Λ criteria. (3L)

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST202.1	Understand the link between multivariate techniques and corresponding univariate techniques	2
ST202.2	Apply multivariate techniques appropriately, undertake multivariate hypothesis tests and draw appropriate conclusions	3
ST202.3	Summarize and interpret multivariate data using appropriate multivariate methods to analyse data with statistical software.	5

ST-204: PARAMETRIC INFERENCE

Course Objectives (CObs):

- To study principles of data reduction such as Sufficiency principle, Likelihood Principle.
- To study important properties of statistics and different methods of estimation techniques.
- To study methods for obtaining optimal estimators in the class of unbiased estimators.
- To study construction of MP test, UMP test and interval estimation.
- To study concept of Bayesian inference.

- **Introduction: (4 Marks)**
  - Introduction of Parametric models, Point estimation, Tests of hypotheses and Interval estimation. (1L)
  - Joint distribution of a sample and sampling distribution of a Statistic. (2L)
  - Likelihood function; examples from standard discrete and continuous models (such as Bernoulli, Poisson, Negative Binomial, Normal, Exponential, Gamma, Pareto etc.) Plotting likelihood functions for these models up to two parameters. (2L)

- **Sufficiency: (10 Marks)**
  - Information in data about the parameters and variation in likelihood function, concept of no information. (1L)
  - Sufficiency, Fisher's concept of sufficiency, Sufficient Statistic, Neyman Factorizability criterion, Likelihood equivalence, Minimal sufficient Statistic. (4L)
  - Invariance property of sufficiency under one-one transformation of sample space. (1L)
  - Exponential families and Pitman families. (3L)
  - Fisher information for one and several parameters models. (2L)

- **Methods of Estimation: (8 Marks)**
  - Maximum Likelihood method. (3L)
  - Methods of moments and percentiles. (2L)
  - Unbiased Estimation. (1L)

- **Minimum Variance Unbiased Estimation: (12 Marks)**
  - UMVUE, Rao-Blackwell Theorem. (2L)
  - Completeness property of family of distributions. (3L)
  - Lehmann-Scheffe-Rao-Blackwell Theorem and its applications. (2L)
  - Necessary and sufficient condition for UMVUE. (1L)
  - Cramer-Rao lower bound approach. (2L)

- **Tests of Hypotheses: (15 Marks)**
  - Concepts of critical regions, Test functions. (1L)
  - Two kinds of errors, Size function, Power function, Level of the test. (2L)
  - Introduction of null and alternative hypotheses with examples. (1L)
  - Most powerful (MP) and Uniformly Most Powerful (UMP) test in the class of size α tests. (1L)
  - Neyman-Pearson Lemma, MP test for simple null against simple alternative hypothesis. (3L)

- UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family. (3L)
- Extensions of these results of Pitman family when only upper or lower end depends on the parameter. (2L)
- MLR property and extension of the above results to the distributions with MLR property. (2L)
- Non-existence of UMP test for simple null against two sided alternatives in one parameter exponential family. (2L)

- **Interval Estimation: (5 Marks)**
  - Confidence level, construction of confidence intervals using pivots, Shortest expected length confidence interval. (3L)
  - Uniformly most accurate one-sided confidence interval and its relation to UMP test for one-sided null against one-sided alternative hypotheses. (2L)

- **Bayesian Estimation: (6 Marks)**
  - Prior distribution, loss function, principle of minimum expected posterior loss, quadratic and other common loss functions, conjugate prior distributions, common examples. (6L)

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST204.1	Understand sufficiency principle, Likelihood Principle as principles of data reduction.	2
ST204.2	Apply important properties of statistics such as sufficiency, completeness, ancillarity and its application to inference study and learn families of distributions such as Exponential family, Pitman family.	3
ST204.3	Estimate unknown parameters using different methods of estimation techniques such as method of moments, maximum likelihood method and obtain lower bounds for variance of an unbiased estimators and related concept of MVUE, MVBUE.	4
ST204.4	Construct MP test, UMP test and knowledge of Interval estimation.	2
ST204.5	Understand the concept of Bayesian inference and its applications.	2

ST-205: PYTHON PROGRAMMING

Course Objectives (CObs):

The learning objectives of this course are:

- To understand why Python is a useful scripting language for developers.
- To learn how to use lists, tuples, and dictionaries and to design and program Python applications.
- To learn how to use import, export, indexing and slicing to access data i.e data handling techniques.
- To learn how to write conditions, loops, decision functions and pass arguments.

- Structure of a Python Program, Elements of Python (4L,4M)

- Introduction to Python: Python Interpreter, Using Python as calculator, Python shell, Indentation. Atoms, Identifiers and keywords, Literals, Strings, Operators (Arithmetic operator, Relational operator, Logical or Boolean operator, Assignment, Operator, Ternary operator, Bit wise operator, Increment or Decrement operator). (8L,8M)

- Creating Python Programs: Input and Output Statements, Control statements (Branching, Looping, Conditional Statement, Exit function, Difference between break, continue and pass.), Defining Functions, default arguments. (6L,6M)

- Structures: Numbers, Strings, Lists, Tuples, Dictionary, Date & Time, Modules, Defining Functions, Exit function, default arguments. (10L,10M)

- Introduction to Advanced Python: Objects and Classes, Inheritance, Regular Expressions, Event Driven Programming, GUI Programming. (12L,12M)

- Basic Statistics in Python with NumPy, PyDev and Jupyter Notebook development environments, Pandas data analysis library, including reading and writing of CSV files, Matplotlib 2D plotting library, Git and GitHub (20L,20M)

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3. Lutz, Mark. *Learning python: Powerful object-oriented programming*. " O'Reilly Media, Inc.", 2013.
4. McKinney, Wes. *Python for data analysis: Data wrangling with Pandas, NumPy, and IPython*. " O'Reilly Media, Inc.", 2012.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST205.1	Design object-oriented programs with Python using functions, loops, list, tuples, dictionaries etc. and classes	6
ST205.2	Build and package Python modules for reusability.	3
ST205.3	Apply the best features statistical thinking and techniques to program real life problems	3

ST-206: PRACTICALS-II

Course Objectives (CObs):

- to deal and process the multivariate data, use R and Matlab to perform exploratory analysis of such a data, apply the multivariate statistical techniques to solve the objective specific problems
- to understand and apply regression model building techniques to various data sets.
- To study sampling distribution of estimators, plotting of likelihood functions, power functions.

A. Practicals based on Linear Models and Regression Analysis. (23 Hours, 16 Marks)

1. Linear Estimation.
2. Analysis of CRD, RBD, LSD.
3. Test of hypotheses for one and more than one linear parametric functions.
4. Multiple Regression:
   - Estimation of regression coefficient, Fitting of multiple linear regression.
   - Testing of hypothesis concerning regression coefficient.
   - Testing of significance of association between the dependent and independent variables.
   - Lack of fit test, Extra sum of squares principle.
5. Orthogonal Polynomials: Fitting of orthogonal polynomials.
6. Residual Analysis.
7. Non-linear regression.
8. Logistic Regression.

B. Practicals based on Multivariate Analysis. (23 Hours, 16 Marks)

1. Model sampling from bivariate distributions (Bivariate exponential, Bivariate Poisson, Bivariate Poisson, Bivariate negative binomial, Bivariate binomial)
2. Model sampling from multivariate normal distribution (including conditional distribution)
3. Estimation of $\underline{\mu}$, Σ-matrix, correlation coefficient, multiple correlation coefficients. Test of significance of multiple and partial correlation coefficients.
4. Applications of Hotelling's T^2.
5. Discriminant Analysis and Classification problem.
6. Principal components.
7. Canonical Correlation.
8. MANOVA

C. Practicals based on Probability Theory and Parametric Inference. (22 Hours, 14 Marks)

1. Plotting c.d.f.
2. Applications and verification WLLN.
3. Applications and verification of CLT.
4. Sampling distribution of Statistics/ Estimators
5. Plotting likelihood functions for standard probability distributions.
6. Unbiased estimation, Moment Estimation, Maximum Likelihood Estimation (discrete, continuous, mixture, truncated distributions.) for parameters and parametric functions.
4. Power of the test, MP test, UMP test (for continuous, mixture and truncated distributions), Minimum sample size needed to attain given power.
5. Interval estimation

D. Practicals based on Python Programming (22 Hours, 14 Marks)

Concerned teacher is expected to design the practical according to the syllabus.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST206.1	Process and analyse the multivariate data, interpret the results etc.	4
ST206.2	Develop and validate the regression models on the basis of data using R software and interpret the results.	3
ST206.3	Understand concept of sampling distribution of estimators, likelihood functions, power functions.	2
ST206.4	Apply object-oriented programs for solving statistical problems with Python using functions, loops, list, tuples, dictionaries, different packages and modules.	3

AUDIT COURSES: SEMESTER-II

AC-201(A): Soft Skills

Course Objectives (CObs):

- To inculcate different soft skills among students.

Unit 1 Introduction to soft skills **2 hrs.**

Formal definition, Elements of soft skills, Soft vs. Hard skills, Emotional quotient, Goal setting, life skills, Need for soft skills, Communication skills, Etiquettes& Mannerism.

Unit 2 Self-Assessment **4 hrs.**

Goal setting, SWOT analysis, attitude, moral values, self-confidence, etiquettes, non-verbal skills, achievements, positive attitude, positive thinking and self-esteem.

Activity: The teacher should prepare a questionnaire which evaluate students in all the above areas and make them aware about these aspects.

Unit 3 **Communication Skills** **8 hrs.**

Types of communication: Verbal, Non-verbal, body language, gestures, postures, gait, dressing sense, facial expressions, peculiarity of speaker (habits).

Rhetoric speech: Prepared speech (topics are given in advance, students get 10 minutes to prepare the speech and 5 minutes to deliver, Extempore speech (students deliver speeches spontaneously for 5 minutes each on a given topic), Storytelling (Each student narrates a fictional or real-life story for 5 minutes each), Oral review (Each student orally presents a review on a story or a book read by them)

Drafting skills: Letter, Report & Resume writing, business letters, reading & listening skills

Activity: The teacher should teach the students how to write the letter, report and build resume. The teacher should give proper format and layouts. Each student will write one formal letter, one report and a resume.

Unit 4 **Formal Group Discussion, Personal Interview & Presentation skills** **4 hrs.**

Topic comprehension, Content organization, Group speaking etiquettes, driving the discussion & skills.

Preparation for personal interview: dress code, greeting the panel, crisp self-introduction, neatness, etiquettes, language tone, handling embarrassing & tricky questions, graceful closing.

Activity: Each batch is divided into two groups of 12 to 14 students each. Two rounds of a GD for each group should be conducted and teacher should give them feedback. Mock interview are to be conducted.

Unit 5 **Aptitude and analytical skills** **8 hrs.**

Quantitative aptitude, Numerical reasoning, verbal reasoning, diagrammatic test, situational tests, logical thinking.

Analytical skills: Definition, Types, problem solving

Unit 6 **Life skills** **4 hrs.**

Time management, critical thinking, sound and practical decision making by dealing with conflicts, stress management, leadership qualities

Activity: The teacher can conduct a case study activity to train students for decision making skills. The teacher should conduct a session on stress management and guide students on how to manage stress. The teacher may conduct a stress relieving activity in the class. He/she may counsel students individually to know their problems and guide them on dealing with them effectively.

Suggested readings:

1. Basics of Communication In English: Francis Sounderaj, MacMillan India Ltd.
2. English for Business Communication: Simon Sweeney, Cambridge University Press
3. An Introduction to Professional English and Soft Skills: Das, Cambridge University Press
4. Quantitative Aptitude: R.S. Agrawal

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC201A.1	Identify their lacunas about some soft skills and try to overcome the same.	2
AC201A.2	Practice learned soft skills in real life and do their jobs more effectively	3

AC-201(B): Practicing Sports Activities

Course Objectives (CObs):

To motivate students towards sports and provide them required training

Sr No.	Name of The Sport/Game (Select one of the following)	Syllabus of the Course	Timing (02 Hours In A Week)	Semester
1	Volleyball	• General Fitness • Basic Fitness • Specific Fitness • History of the Game • Basic Skill of the Game • Major Skill of the Game • Technique & Tactics of the Game • Game Practice	Morning : 07 to 09 AM OR Evening : 05 to 07 PM	Total 30 Hours in Each Semester
2	Athletics			
3	Badminton			
4	Cricket			
5	Basketball			
6	Handball			
7	Kabaddi			
8	Kho-Kho			
9	Table-Tennis			
10	Swimming			

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC201B.1	Identify one or more sports of their choice and develop more interest to participate at University/National level sport events.	2
AC201B.2	Practice the learned sports activities regularly in real life	3

AC-201(C): Practicing Yoga

Course Objectives (CObs):

To motivate students towards yoga and provide them required training

- Yog: Meaning, Definition & Introduction, Objectives
- Primary Introduction of Ashtanga Yoga
- Preparation of Yogabhyas
- Omkar Sadhana, Prayer, Guru Vandana
- Sukshma Vyayamas
- Suryanamaskar (12 Postures)
- Asanas :
  - Sitting (Baithaksthiti)- Vajrasana, Padmasan, Vakrasan, Ardha-Pashchimotanasanan
  - Supine (Shayansthiti) - Uttan Padaasan(Ekpad/Dwipad), Pavanmuktasana, Viparitakarani Aasan, Khandarasan, Shavasana
  - Prone (Viparitshayansthiti) - Vakrahasta, Bhujangasana, Saralhasta Bhujangasana, Shalabhasana(Ekpad/Dwipad), Makarasana
  - Standing (Dhandsthiti) - Tadasana , TiryakTadasana, Virasana, Ardh Chakrasana
- Primary Study of Swasana: Dirghaswasana, Santhaswasana, JaladSwasana - 6 Types
- Pranayama : Anuloma-viloma, Bhramari

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC201C.1	Identify and practice some Yoga asanas regularly in their life to remain healthy.	2
AC201C.2	Provide guidance and practice about Yoga to their friends, parents and relatives.	3

AC-201(D): Introduction to Indian Music

Course Objectives (CObs):

To motivate students towards Indian music and provide them minimum required training

- Definition and brief about generation of Swar, Saptak, Thaat, Raag, Aavartan, Meend, Khatka, Murkee, Taal, Aalaap etc.
- Taal and its uses - Treetaal, Daadraa, Zaptaal, Kervaa.
- Information of Badaakhyaal, Chhotaakhyaal (one), Sargam, Lakshangeet (information)
- Detailed information of Tambora
- Detailed information of Harmonium and Tablaa.
- Five filmy songs based on Indian Classical Music (Theory and Presentation)
- Sound Management - Basic information of Sound Recording (including Practicals)
- Composition of Music as per the Story

- Preparing news write-ups of the Seminars, Library Musical Programmes held at the nearest Akashwani, by personal visits

Course Outcomes (COts):

After the completion of the course, students will be able to

Course Outcome	Course Outcome	Cognitive Level
AC201D.1	Identify different types of Indian music	3
AC201D.2	Develop more interest to learn and practice Indian music	4

ST-301: ASYMPTOTIC AND NONPARAMETRIC INFERENCE

Course Objectives (CObs):

- To study important features of large sample theory.
- To construct likelihood ratio test (LRT) for testing of hypothesis, obtaining asymptotic confidence interval (ACI) of parameter.
- To study different nonparametric tests.

- Review of convergence in probability and convergence in distribution, Cramer and Slutsky's Theorems. (2L,2M)
- Consistent Estimation of real and vector parameter. Invariance of Consistent estimator under continuous transformation. (3L,3M)
- Consistency of estimators by method of moments, and method of percentiles, Mean squared error criterion. (4L,4M)
- Asymptotic relative efficiency, Error probabilities and their rates of convergence, Minimum sample sizes required to attain given level of accuracy. (4L,4M)
- Consistent Asymptotic Normal (CAN) estimator, Invariance of CAN estimator under differentiable transformation. (4L,4M)
- CAN property of estimators obtained by moments and percentiles. (3L,3M)
- CAN estimators obtained by moment and MLE method in one parameter exponential family, Extension of multi-parameter exponential family. (3L,3M)
- Examples of consistent but not asymptotically normal estimators. (2L,2M)
- Method of maximum likelihood, CAN estimators for one-parameter Cramer family, Cramer-Huzurbazar theorem, Solution of likelihood equations, Method of scoring, Newton-Raphson and other iterative procedures. (6L,6M)
- Fisher Lower Bound to asymptotic variance, extension to multi-parameter cases (without proof.) Multinomial distribution with cell probabilities depending on a parameter. (3L,3M)
- MLE in Pitman Family and Double Exponential distribution, MLE in censored and truncated distribution. (3L,3M)
- Likelihood Ratio Test (LRT), asymptotic distribution of LRT statistic, Wald Test, Rao's score test, Pearson χ^2 test for Goodness of fit, Barlett's Test for homogeneity of variances. Large Sample Tests and confidence intervals based on CAN estimators, Variance stabilizing transformation and large sample tests. Consistency of Large Sample Tests. Asymptotic power of large sample tests. (8L,8M)
- Nonparametric Statistical Inference. (15L,15M)
  - Introduction to Nonparametric Inference.
  - U-Statistics.
  - Some Single-Sample problems.
  - Some Two-Sample problems.
  - Test of Independence.
  - Some Applications of Order Statistics.

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7. Rao, C.R. (1973): Linear Statistical Inference.
8. Dudewicz, E.J. and Mishra, S.N.(1988), Modern Mathematical Statistics. Wiley

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST301.1	Apply large sample properties of an estimator such as consistency, CAN estimator and different methods to construct such estimators.	3
ST301.2	Understand large sample properties of MLEs.	2
ST301.3	Construct likelihood ratio test (LRT) for testing of hypothesis with different examples, obtain asymptotic confidence interval (ACI) of a parameter.	3
ST301.4	Understand knowledge about non-parametric method and some important non-parametric tests.	2

ST-302: DESIGN, PLANNING AND ANALYSIS OF EXPERIMENTS

Course Objectives (CObs):

- How to plan, design and conduct experiments efficiently and effectively by applying the basic principles of designs of experiments
- To study various characterizations, properties and analysis of designs such as CRD, RBD, LSD, BIBD, YSD PBIBD, factorial and fractional factorial designs etc.
- To study Response Surface models, Taguchi designs, orthogonal arrays and matrix experiments, use of signal-to-noise ratio in analysis of Taguchi designs, ANOMs etc.

- Basic principles of design of experiments:Randomization, replications, local control. (2L,2M)
- Concept of Fixed effect models, Random effect models and Mixed effect models. (1L,1M)
- One way classification models, random effect model for one way classification. (5L,5M)
- Two way classification model with equal number of observations per cell with and without interactions. (6L,6M)
- General two way block designs, various characteristics of general two way block design: connectedness, balancedness and orthogonality, Balanced Incomplete Block Design (BIBD), PBIBD with two associate classes, LSD and Youden Square design. (10L,10M)
- Analysis of covariance (ANCOVA) in a general Gauss-Markov model, Applications and need of ANCOVA technique, Analysis of covariance in one-way and two-way classification model.

(4L,4M)

- 2^k Full factorial designs: diagrammatic representation of main effects and first order interactions in the model, analysis of single as well as more than one replicates using ANOVA, technique of confounding, total and partial confounding in 2^k Full factorial designs and analysis of such designs. (5L,5M)
- Total confounding of 2^k design in 2^p blocks with $k > p \geq 2$, Partial confounding in 2^p blocks, p=2,3, analysis of designs with treatments confounded in more than two blocks. (5L,5M)
- Two-level-fractional factorial experiments, Resolution of a design (III, IV & V), abbreviation of a design, aliases, generators of the design, complete defining relation etc. (4L,4M)
- Concept of rotatable design. Central composite designs, 3^2 designs: contrasts for linear and quadratic effects, statistical analysis of 3^2 design. (5L,5M)
- Response surface methodology (RSM): linear and quadratic model, determination of stationary point, ridge systems, multiple responses, blocking in RSM, Plackett-Burman design. (5L,5M)
- Taguchi (orthogonal array) methods: concept of loss function, S/N ratio, Linear graphs ANOM inner and outer arrays, ANOVA. (8L,8M)

REFERENCES

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5. Phadke, M.S. (1989) Quality Engineering through Robust Design, Prentice Hall.
6. Kuehl R.O.(1994). Statistical Princpals of Research Design and Analysis. Duxbury Press.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST302.1	Understand how to use designed experiments to achieve breakthrough improvements in process efficiency and quality, have a general insight into how data analysis is done in connection to designed experiments	2
ST302.2	Critically review basic concepts and models of experimental design.	4
ST302.3	Analyse the results of a designed experiment in order to conduct the appropriate statistical analysis of the data, interpret statistical results from an experiment and report them in non-technical language.	4

ST-303: TOTAL QUALITY MANAGEMENT (TQM), STATISTICAL PROCESS CONTROL (SPC) AND RELIABILITY

Course Objectives (CObs):

- To describe the concept of variation and role of statistics in Quality Improvement through SPC tools.
- To make aware the students about the Industrial production processes and applications of SPC tools for monitoring those processes.
- To prepare students to carry out process capability analysis based on real life process data.
- To describe some mathematical and applied terminologies of reliability theory.

- Total Quality Management. (8L,8M)
  - Concept of Quality, Quality improvement, Quality philosophy.
  - Introduction of TQM, evaluation of Total Quality.
  - Some important TQM concepts.
  - TQM Gurus' Ideas.
  - Japanese 5-S Practice.
  - The Impact of National and International Quality Awards on TQM.
  - The European Quality Award.
  - The Deming Application Prize.
  - Six Sigma and other Extensions of TQM.
  - Quality systems.
  - The ISO 9000 and other Quality systems.

- Review of some Statistical methods useful in Quality Improvement. (2L,2M)
  - Concept of variation, systematic variation, random variation, stable industrial processes.
  - Describing variation through graphical and numerical methods.
  - Some important Discrete and continuous probability distributions useful in quality control and improvement.
  - Some useful approximations of Distributions.

- Statistical Process Control (SPC).
  - Introduction of SPC. (3L,3M)
    - Basic concept of process monitoring and control.
    - Seven tools of SPC.
    - General theory of Control charts.
    - Different types of limits, Specification limits, Natural tolerance limits, Control limits, Warning limits.
    - OC Curve and ARL of control charts.
  - Control Charts for Attributes. (4L,4M)
    - Control chart for fraction nonconforming.
    - Control chart for fraction nonconformities (defects)
    - OC Curves for Attributes control charts.
  - Control Charts for Variables. (7L,7M)
    - Statistical basis of the charts for variables.

- $\overline{X}$, R, S, $\overline{X}$ *and* R, $\overline{X}$ *and* S, $\overline{X}$ *and* S^2 Control Charts.
- Median chart and Midrange chart.
- Control charts for Individual Measurements.
- Special control charts: CUSUM, EWMA control charts.

- Process Capability Analysis. (7L,7M)
  - Capable process and Process capability.
  - Process Capability Analysis using Histogram or Probability plot.
  - Process Capability indices under normal distribution of quality characteristic.
    - Capability indices C_p, C_{pk}, C_{pm}.
    - Connection between proportion of nonconforming and C_p, C_{pk}.
    - Estimation, C.I. and tests of hypotheses relating to C_p.
  - Process Capability Analysis for non-normal data.
  - Process Capability Analysis for Designed Experiments.
  - Gauge and Measurement system capability studies.
  - Setting specification limits on discrete components, linear and nonlinear combinations.
  - Estimating the Natural tolerance limits of a process.
- SPC for short production. (1L,1M)
- Modified and Acceptance control charts. (1L,1M)
- Group control chart. (1L,1M)
- SPC with autocorrelated process data (2L,2M)
- Multivariate Quality control. (2L,2M)
- Engineering process control(EPC) and SPC (2L,2M)
- Acceptance Sampling. (8L,8M)
  - Single, double and sequential sampling plans for attributes and their properties.
  - Curtailed double sampling plans, operating characteristics functions and other properties of the sampling plans.
  - Sampling plans with rectification. OC, ASN, ATI, AOQ curves, AOQL, Designing of sampling plan. Dodge-Romig acceptance sampling plans.
  - Plan for inspection by variables for one-sided and two-sided specifications; AQL based sampling plans.

- Elements of Reliability: (12L,12M)

  Components and systems, binary coherent structure k-out-of –n: G structure, bridge structure. Cuts and Paths, minimal path sets and minimal cut sets. Reliability of coherent system, bonds on system reliability. Structural and reliability importance of components, Hazard function, distribution with DFR and IFR.

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST303.1	Describe the concept of variation, Quality, TQM tools and terminologies useful as per standards of ISO.	2
ST303.2	Describe and apply SPC tools useful for Quality control and Quality improvement.	2
ST303.3	Apply different graphical tools useful in SPC and interpret their uses.	3
ST303.4	Describe the role of Process Capability Analysis and its measures useful in SPC.	2
ST303.5	Explain and Apply different terminologies useful in mathematical reliability based importance of components under different coherent structures.	3

ST-304: STOCHASTIC PROCESSES

Course Objectives (CObs):

- To study of the basic concepts of the theory of stochastic processes;
- Study of various properties and characteristics of stochastic processes;
- Study of the methods for describing and analysing complex stochastic models.

- **Introduction: Stochastic Processes, Markov chains (14 Marks)**
  - Review of conditional probability and Expectation with problems. (2L)
  - Introduction to Stochastic Processes, Classification of Stochastic Processes according to state space and time domain. (1L)
  - Finite and countable state space Markov chains (Definitions and examples). (2L)
  - Chapman-Kolmogorov equations, Calculation of n-step transition probability and its limit. (2L)

- Stationary distribution of Markov chains. (2L)
- Classification of states, Period of the state, Transient and recurrent Markov chain and related results. (4L)
- Random walk and gambler's ruin problem. (2L)
- First passage time and other problems with applications. (2L)
- Applications of Markov Chains in Social, Biological and Physical Sciences. (1L)

- **Branching Process: (6 Marks)**
  - Golton-Watson branching process. (2L)
  - Probability of ultimate extinction, Distribution of population size. (2L)
  - Applications. (1L)

- **Discrete state space continuous time Markov Chain. (12 Marks)**
  - Definition and examples. (1L)
  - Markov Pure jumps processes. (2L)
  - Kolmogorov's differential equations. (2L)
  - Poisson process (Definitions, properties and applications). (3L)
  - Birth and death processes, Machine repairmen problem. (2L)
  - Wiener process as a limit of random walk. (2L)

- **Simple Queuing Systems: (6 Marks)**
  - $M/M/1, M/M/\infty, M/M/S$ queuing systems and their applications. (2L)
  - Stationary solution for these systems using birth and death process approach. (2L)

- **Renewal Theory: (10 Marks)**
  - Renewal process (Definition and examples) (2L)
  - Elementary renewal theorem and its applications (2L)
  - Statement and uses of key renewal theorem (1L)
  - Renewal reward process, Regenerative Process, Semi-Markov process. (2L)
  - Age of renewal process and residual life in renewal processes and their distributions. (2L)
- **MCMC Algorithm:(3 Marks)** (3L)

- **Inference in Markov chains: (9 Marks)**
  - Estimation of transition probabilities, estimation of functions of transition probabilities in Markov chains, Testing of order of a Markov chains, Parametric models and their goodness of fit. (9L)

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Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST304.1	Clarify the power of stochastic processes and their range of applications;	2
ST304.2	Demonstrate essential stochastic modelling tools including Markov chains and queuing theory;	2
ST304.3	Formulate and solve problems which involve setting up stochastic models	6

ST-305(A): DESIGN AND ANALYSIS OF CLINICAL TRIALS

Course Objectives (CObs):

- The basic principles for design of randomized clinical trials and how they should be reported.
- Introduction to terminology used in clinical trials and the several common designs used for clinical trials, such as parallel and cross-over designs.
- Techniques of clinical trials, like randomization and blinding of treatment, Analysis and interpretation of the experiments.

- Introduction to Clinical Trials(CTs) (4L,4M)
  - Need and ethics of CTs
  - History of CTs.
  - Regulatory process and Requirement.
  - Investigational New Drug Application.
  - New Drug Application.
  - Overview of Phases I to IV trials
- Basic Design Consideration. (5L,5M)
  - Introduction.
  - Patient Selection.
  - Selection Control.
  - Statistical Consideration.
- Randomization and Blinding. (6L,6M)
  - Randomization Models.
  - Randomization Methods.

- Implementation of Randomization.
- Generalization of Controlled Randomized Trials.
- Blinding.

- Classification Clinical Trials. (5L,5M)
  - Multicenter Trial.
  - Active Control Trial.
  - Combination Trial.
  - Equivalence Trial.
- Designs of Clinical Trials. (6L,6M)
  - Parallel Designs.
  - Crossover Designs.
  - Balanced Incomplete Block Designs
  - Titration Designs.
  - Enrichment Designs.
- Bioavailability and Bioequivalence Studies. (6L,6M)
  - History of Bioavailability Studies.
  - Formulation and Routes of Administration.
  - Pharmacokinetic Parameter.
  - Clinically Importance Differences.
  - Assessment of Bioequivalence.
  - Decision Rules and Regulatory Aspect.
  - Statistical Consideration.
- Statistical Inference for Effects from a Standard 2x2 Crossover Design. (8L,8M)
  - The Carry-over Effect.
  - The Direct Drug Effect.
  - The Period Effect.
  - The Analysis of Variance.
- Analysis of Continuous Data. (6L,6M)
  - Estimation.
  - Test Statistics.
  - Analysis of Variance.
  - Analysis of Covariance.
  - Nonparametric.
  - Repeated Measure
- Analysis of Categorical Data. (6L,6M)
  - Statistical Inference for One Sample.
  - Inference for Independent Sample.
  - Ordered Categorical Data.
  - Combing Categorical Data.
  - Model-Based Method.
  - Repeated Categorical Data.
- Power and Sample size Determination. (4L,4M)
  - Hypothesis and Type I and Type II Errors.
  - Power and Relative Efficiency
  - Sample size Determination.
- Assumptions and Outlier Detection. (4L,4M)
  - Tests for Assumption.

- The Definition of Outlying Observation.
- Detection of Outlying Subject.
- Detection of Outlying Observation.

REFERENCES

1. J.L.Fleiss (1989) The Design and Analysis of Clinical Experiments. Wiley and Sons.
2. E.Marubeni and M.G.Valsecchi (1994). Analyzing Survival Data from Clinical Trials and Observational studies, Wiley and Sons.
3. Shein-Chung Chow and Jen-pei Liu, Design and Analysis of Clinical trial, Wiley and Sons.
4. Shein-Chung Chow and Jen-pei Liu, Design And Analysis of Bioavailability and Bioequvalence Studies, Marcel Dekker,Inc
5. S.Paintadosi.(1997) Clinical Trials: A Methodologic Perspective. Wiley and Sons.
6. L.M.Friedman, C.Furburg, D.L.Demets (1998). Fundamentals of Clinical Trials, Springer Verlag.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST305A.1	Reduce the bias and variability involved during conduction of Clinical trials.	3
ST305A.2	Estimate the true therapeutic effect of the drug	4
ST305A.3	Analyse the outcomes of clinical experiments through various statistical techniques	4

AUDIT COURSES: SEMESTER-III

ST-305(B): ECONOMETRICS

Course Objectives (CObs):

- To gain knowledge and skills in econometrics to economic issues.
- perform relevant statistical analyses of economic data using statistical software.
- interpret results of empirical analyses and draw conclusions based on these analyses.

Unit I: **(30L)**

Brief review of topics in Multiple Linear Regression Analysis; Forecasting, Econometric tests on Heteroscedasticity and Autocorrelation; Restricted Regression; Errors in Variables; Functional Form and Structural Change; Stochastic Regression; Instrumental Variable (IV) Estimation; Large Sample Properties of Least Square and IV estimators; Panel Data Models; Systems of Regression Equations- Seemingly Unrelated Regression Equations (SURE) & Multivariate Multiple Linear Regression;

Unit II: **(30L)**

Simultaneous Equation Models- Structural and Reduced forms, Rank and Order conditions for Identifiability, Indirect Least Squares, 2-stage Least Squares and Limited Information Maximum Likelihood methods of estimation, k-class estimators and Full Information

Maximum Likelihood Estimation; Models with lagged variables- Autoregressive Distributed Lag (ARDL) Models and Vector Autoregressive (VAR) Models; Topics on Econometric Time Series Models- Autoregressive and Generalized Autoregressive Conditionally Heteroscedastic (ARCH & GARCH) Models, Unit Root, Cointegration and Granger Causality.

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1. Apte PG (1980); Text book of Econometrics. Tata McGraw Hill.
2. Carmer, J.S. (1971) Empirical Econometrics, North Holland
3. Gujarathi, D (2003): Basic Econometrics, McGraw Hill.
4. Intrulligator, MD (1980): Econometric models-Techniques and applications, Prentice Hall of India.
5. Johnston, J. (1984) : Econometric methods. Third edition, McGraw Hill.
6. Klein, L.R. (1962) : An introduction to Econometrics, Prentice Hall India.
7. Koutsoyiannis, A. (1979) : Theory of Econometrics, Macmillan Press.
8. Malinvaud, E (1966) : Statistical methods of Econometrics, North Holland.
9. Theil, H. (1982) : Introduction to the theory and practice of Econometrics, John Wiley.
10. Walters, A. (1970) : An introduction to Econometrics, McMillan & Co.
11. Wetherill, G.B. (1986) : Regression analysis with applications, Chapman Hall.
12. Greene, William: Econometric Analysis, Prentice Hall, Sixth Condition, 2008.
13. Judge, G.G. Griffiths, R.C. Hill, T. Lee and H. Lutkepohl: The Theory and Practice of Econometrics, John Wiley, 1985.
14. Maddala, G.S.: Introduction to Econometrics, Third edition, John Wiley, 2002.
15. Johnston, J and DiNardo,J.: Econometric Methods, Fourth edition, McGraw Hill, 1997.
16. Woolridge, J.M.: Introductory Econometrics- A Modern Approach, South-Western College, Publications, 2002.
17. Baltagi, Badi H: Econometrics, Second edition, Springer-Verlag, 1999.
18. Ullah, A. and H.D. Vinod: Recent Advances in Regression Models, Marcel Dekker, 1981.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST305B.1	Identify the suitable methods that is relevant for different problems, and advantages and disadvantages of different empirical approaches.	2
ST305B.2	Estimate and test in Econometric problems using statistical techniques like multiple regression analysis, multivariate analysis, analysis of variance, correlation analysis, logistic regression analysis and exploratory factor analysis.	4
ST305B.3	Interpret results of empirical analyses and draw conclusions based on these and make qualified choices between different models.	3

ST-306: PRACTICALS - III

(By using statistical software and/or Computer programming language)

Course Objectives (CObs):

- To demonstrate CANness of estimators, obtaining MLE by numerical methods, construct ACI, analysing data by appropriate non-parametric tests.
- Analyse different designed experiments' data, interpret the results through AMONs, interaction plots, contours and response surface plots, test specific hypothesis of interest etc.
- To teach SPC tools through statistical software.

A. Practicals based on Asymptotic and Nonparametric Inference (16 Hrs,10M)

1. Demonstrating consistency and CANness of consistent estimators.
2. Demonstration of consistency and asymptotic non-normality of estimator that is consistent but not CAN.
3. Computation of moment estimators and demonstration of their asymptotic distributions.
4. Verification of invariance property of consistent and CAN estimators under continuous transformation.
5. Generating consistent estimators by method of percentile.
6. MLE by methods of scoring.
7. Comparison of consistent estimator
   On the basis of their MSE's of different estimators.
   On the basis of requirement of minimum sample size.
8. ACI, Testing of hypothesis by likelihood ratio tests, computation and plotting of power function of test.
9. Fitting of distributions to sample data using following tests:
   Chi-square goodness of fit test
   Kolmogorov Smirnov goodness of fit test
   Lilliefor's goodness of fit test
10. Practical on one sample location problem (i) Sign test (ii) Wilcoxon Signed rank test
11. Practical on two sample location problem
    (i) Wilcoxon Rank sum test (ii) Mann Whitney U test
12. Practical on k sample Kruskal Wallis test, Friedman test.

B. Practicals based on Design, Planning and Analysis of Experiments (22 Hrs,15M)

1. Estimation of parameters, testing various hypothesis and analysis of variance for the following linear models:
   - Two-way classification model with r observations per cell with/without interaction.
   - Two-way classification model with unequal observations per cell
   - Random effect model for one-way classification model
2. Estimation of parameters, testing various hypothesis and analysis of covariance for the following linear models:
   - One-way classification model with one or more than one concomitant variable.
   - Two-way classification model with one or more than one concomitant variable.
3. Analysis of BIBD

4. Identification/verification of various properties (balancedness/connectedness, orthogonality) of the given design.
5. Generation and analysis of two-level factorial designs, main effect and interaction plots.
6. Analyzing two-level factorial designs with
   (i) Total confounding (ii) Partial confounding (iii) single replicate
7. Generation and analysis of two-level fractional factorial designs.
8. Analysis of 3^2 factorial design using response surface model (RSM), main effect and interaction plots.
9. Generating CCD and analysis of CCD with RSM, contour plots, response surface plots, calculation of stationary point and optimum response.
10. Generation and analysis of Taguchi orthogonal array designs.

C. Practicals based on course ST-303 (22 Hrs,15M)

1. Graphical tools used in SPC with their interpretations: Stem-and-leaf plot, Box plot, Histogram, Probability Plots, cause and effect diagram, Pareto chart, Scatter plot, Check sheet, Control chart.
2. Accessing normality of data
3. Identification of probability distribution of quality characteristics.
4. Plotting and interpretation of Control chart for attribute.
5. Plotting and interpretation of Control chart for variable.
6. Plotting Multivariate Control chart.
7. Process capability analysis for normal data.
8. Process capability analysis for non-normal data.
9. Gauge capability analysis.
10. Control charts for Short Production Runs
11. Single and double sampling plans for attributes: plotting OC, ASN, ATI, AOQ curves, finding AOQL.
12. Single sampling plan for variables.
13. Calculation and/or estimation of reliability in parallel, series and k-out-of-n structures.

D. Practicals based on Stochastic Processes (15 Hrs, 10M)

1. Calculation of n-step transition probabilities and limiting distribution in Markov chain.
2. Realization of Markov chain.
3. Realization of Branching process.
4. Simulation of Poisson process.
5. Simulation of Random Walk.
6. Simulation of Renewal process.
7. Simulation of $M/M/1$ queuing system.
8. Simulation of Brownian Motion
9. Estimation of transition probability of Markov chain using realization.
10. MCMC Techniques

E. Practicals based on Design and Analysis of Clinical Trials (15Hrs, 10M)

1. Demonstration of *p*-value, type I and type-II errors using Z-test, t-test, two sample t-test, paired t-test and its interpretation and role in testing of hypothesis in CTs.
2. Relation between sample size and power of the test.

3. Randomization Methods.
4. Statistical Analysis for Parallel Designs.
5. Statistical Analysis for Standard 2x2 Crossover Designs.
6. Analysis of continuous data based on repeated measures under CTs.
7. Nonparametric Tests.
8. Analysis of Categorical Data.
9. Outlier Detection in CTs.
10. Estimation of Pharmacokinetic parameters.

OR

Practicals based on Econometrics **(15Hrs, 10M)**

Concerned teacher is expected to design the practicals according to the syllabus.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST306.1	Demonstrate consistency and asymptotic normality of estimators, for testing of hypothesis use of appropriate non-parametric tests using R software	2
ST306.2	Solve objective specific problems through analysis of multivariate data with continuous response and qualitative and/or quantitative predictors.	3
ST306.3	Apply different SPC tools to analyse Industrial production data.	4
ST306.4	Simulate stochastic processes and reliability systems and estimate different parameters of interest.	3
ST306.5	Analyse the outcomes of clinical experiments through various statistical software.	4

AUDIT COURSE: SEMESTER-III

AC-301(A): Computer Skills

Course Objectives (CObs):

- To inculcate different daily useful computer skills among students.

Unit 1 **Elements of Information Technology** **2 hrs**

1.1 Information Types: Text, Audio, Video, and Image, storage formats
1.2 Components: Operating System, Hardware and Software, firmware
1.3 Devices: Computer, Mobile Phones, Tablet, Touch Screen, Scanner, Printer, Projector,smart boards
1.4 Processor & Memory: Processor functions, speed, Memory types: RAM /ROM /HDD /DVD-ROM/Flash drives, memory measurement metrics

Unit 2 **Office Automation-Text Processing** **5 hrs**

2.1 Views: Normal View, Web Layout View, Print Layout View, Outline View, ReadingLayout View

2.2 Working with Files: Create New Documents, Open Existing Documents, SaveDocuments to different formats, Rename Documents, Close Documents

2.3 Working with Text: Type and Insert Text, Highlight Text, Formatting Text, Delete Text,Spelling and Grammar, paragraphs, indentation, margins

2.4 Lists: Bulleted and Numbered Lists,

2.5 Tables: Insert Tables, Draw Tables, Nested Tables, Insert Rows and Columns, Moveand Resize Tables, Moving the order of the column and/or rows inside a table, TableProperties

2.6 Page Margins, Gutter Margins, Indentations, Columns, Graphics, Print Documents,

2.7 Paragraph Formatting, Paragraph Attributes, Non-printing characters

2.8 Types of document files: RTF, PDF, DOCX etc.

Unit 3 Office Automation-Worksheet Data Processing **5 hrs**

3.1 Spreadsheet Basics: Adding and Renaming Worksheets, Modifying Worksheets,

3.2 Moving Through Cells, Adding Rows, Columns, and Cells, Resizing Rows and Columns, Selecting Cells, Moving and Copying Cells

3.3 Formulas and Functions: Formulas, Linking Worksheets, Basic Functions, AutoSum, Sorting and Filtering: Basic Sorts, Complex Sorts, Auto-fill, Deleting Rows, Columns, and Cells

3.4 Charting: Chart Types, drawing charts, Ranges, formatting charts

Unit 4 Office Automation- Presentation Techniques and slide shows **6 hrs**

4.1 Create a new presentation, AutoContent Wizard, Design Template, Blank Presentation,Open an Existing Presentation, PowerPoint screen, Screen Layout

4.2 Working with slides: Insert a new slide, Notes, Slide layout, Apply a design template,Reorder Slides, Hide Slides, Hide Slide text, Add content, resize a placeholder or textbox, Move a placeholder or text box, Delete a placeholder or text box, Placeholder orText box properties, Bulleted and numbered lists, Adding notes

4.3 Work with text: Add text and edit options, Format text, Copy text formatting, Replacefonts, Line spacing, Change case, Spelling check, Spelling options

4.4 Working with tables: Adding a table, Entering text, Deleting a table, Changing rowwidth, Adding a row/column, Deleting a row/column, Combining cells ,Splitting a cell,Adding color to cells, To align text vertically in cells, To change table borders,Graphics, Add clip art, Add an image from a file, Save & Print, slide shows, slideanimation/transitions.

Unit 5 Internet & Applications: **4 hrs**

5.1 Computer Network Types: LAN, PAN, MAN, CAN, WAN, Defining and describing theInternet, Brief history, Browsing the Web, Hypertext and hyperlinks, browsers,Uniform resource locator

5.2 Internet Resources: Email, Parts of email,

5.3 Protecting the computer: Password protection, Viruses, Virus protection software,Updating the software, Scanning files, Net banking precautions.

5.4 Social Networking: Features, Social impact, emerging trends, issues, Social Networking sites: Facebook, Twitter, linkedin, orkut, online booking services
5.5 Online Resources: Wikipedia, Blog, Job portals, C.V. writing
5.6 e-learning: e-Books, e-Magazines, e-News papers, OCW(open course wares): Sakshat(NPTEL) portal, MIT courseware

Unit 6 Cloud Computing Basics **3 hrs**

6.1 Introduction to cloud computing
6.2 Cloud computing models: SAS, AAS, PAS
6.3 Examples of SAS, AAS, PAS (DropBox, Google Drive, Google Docs, Office 365 Prezi, etc.)

Suggested readings:

1. TCI, "Introduction to Computers and Application Software", Publisher: Jones & Bartlett Learning, 2010, ISBN: 1449609821, 9781449609825
2. Laura Story, Dawna Walls, "Microsoft Office 2010 Fundamentals", Publisher: Cengage Learning, 2010, ISBN: 0538472464, 9780538472463
3. June Jamrich Parsons, Dan Oja, "Computer Concepts Illustrated series", Edition 5, Publisher Course Technology, 2005, ISBN 0619273550, 9780619273552
4. Cloud computing online resources

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC301A.1	Identify their lacunas about some computer skills and try to overcome the same.	2
AC301A.2	Practice the learned computer skills in real life and do their jobs more effectively	3

AC-301(B): Cyber Security

Course Objectives (CObs):

- To make students aware of different daily useful cyber security skills/rules.

Unit 1 Networking Concepts Overview **3 hrs**

Basics of Communication Systems, Transmission Media, ISO/OSI and TCP/IP models, Network types: Local Area Networks, Wide Area Networks, Internetworking, Packet Formats, Wireless Networks: Wireless concepts, Advantages of Wireless, Wireless network architecture, Reasons to use wireless, Internet

Unit 2 Security Concepts **7 hrs**

Information Security Overview, Information Security Services, Types of Attacks, Goals for Security, E-commerce Security, Computer Forensics, Steganography.
Importance of Physical Security, Biometric security & its types, Risk

associated with improper physical access, Physical Security equipments.
Passwords: Define passwords, Types of passwords, Passwords Storage – Windows & Linux.

Unit 3 **Security Threats and vulnerabilities** **7 hrs**

Overview of Security threats, Hacking Techniques, Password Cracking, Types of password attacks, Insecure Network connections, Wi-Fi attacks & countermeasures, Information Warfare and Surveillance.
Cyber crime: e-mail related cyber crimes, Social network related cyber crimes, Desktop related cyber crimes, Social Engineering related cyber crimes, Network related cyber crimes, Cyber terrorism, Banking crimes

Unit 4 **Cryptography** **5 hrs**

Understanding cryptography, Goals of cryptography, Types of cryptography, Applications of Cryptography, Use of Hash function in cryptography, Digital signature in cryptography, Public Key infrastructure

Unit 5 **System & Network Security** **3 hrs**

System Security: Desktop Security, email security: PGP and SMIME, Web Security: web authentication, Security certificates, SSL and SET, Network Security: Overview of IDS, Intrusion Detection Systems and Intrusion Prevention Systems, Overview of Firewalls, Types of Firewalls, VPN Security, Security in Multimedia Networks, Fax Security.

Unit 6 **OS Security** **2 hrs**

OS Security Vulnerabilities updates and patches, OS integrity checks, Anti-virus software, Design of secure OS and OS hardening, configuring the OS for security, Trusted OS.

Unit 7 **Security Laws and Standards** **3 hrs**

Security laws genesis, International Scenario, Security Audit, IT Act 2000 and its amendments.

Suggested readings:

1. Skills Factory, Certificate in Cyber Security, Text Book Special edition, Specially published for KBC NMU, Jalgaon
2. BPB Publication, "Fundamentals of Cyber Security", Mayank Bhushan, Rajkumar Singh Rathore , Aatif Jamshed
3. CreateSpace Independent Publishing Platform, "Cyber Security Basics", Don Franke, ISBN-13: 978-1522952190ISBN-10: 1522952195
4. Online references

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC301B.1	Practice learned cyber security skills/rules in real life.	3
AC301B.2	Provide guidance about cyber security skills/rules to their friends, parents and relatives	2

AC-301(C): BASE STATISTICAL ANALYSIS SOFTWARE (SAS)

Course Objectives (CObs):

- To learn SAS Studio and Enterprise Guide programming environment
- To deal with various types of data and importing and exporting data sets
- Apply various statistical methods using SAS

- Introduction to SAS (3L)
- Accessing and describing Data (3L)
- Creating Data Structures (3L)
- Managing and formatting Data (3L)
- Statistical Testing (6L)
- Statistical Analysis and Modelling (6L)
- Exporting Data and Generating Reports (4L)
- Handling Errors (2L)

REFERENCES

1. Cody, Ron. *An introduction to SAS university edition*. SAS Institute, 2018.
2. Cody, Ron. *Learning SAS by example: a programmer's guide*. SAS Institute, 2018.
3. Delwiche and Slaughter: *The Little SAS Book*, 5th Edition.
4. Cody and Smith: *Applied Statistics and the SAS Programming Language*, 5th Edition.
5. McDaniel, Stephen, and Chris Hemedinger. *SAS for Dummies*. John Wiley & Sons, 2007.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
AC301C.1	Understand the SAS Studio and Enterprise Guide programming environment	2
AC301C.2	Create, Read and combine various types of data into SAS data sets	6
AC301C.3	Apply various statistical methods using SAS	3
AC301C.4	Create Report and enhance listing and summary reports	6

AC-301 (D): REVIEW OF RESEARCH PAPER

Course Objectives (CObs):

- To guide students for reading of research articles and writing its review.
- To develop research interest of students

- Types of research article: scientific research articles, review articles, theoretical, case studies, application oriented etc., selecting the article for the literature review based on topic of interest, motivation of choosing the article, identifying what is being examined, researched and discussed in the article, overviewing the research references used in article, provide background and context. (8L)

- Definitions of new terms used, results, theorems etc, filling the gaps in the literature that are related to the article. (4)
- Theoretical frames used, purpose, methodology and methods used in article, simulation and numerical studies performed, major findings of the research article, outcomes of the study, applications of the results of the study. (6L)
- strength and limitations of the research, Possible extensions of the research. (2L)
- Review writing by student. (10L)

Note: Each student is required to submit a report of the article/s reviewed.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
AC301D.1	Search scientific research articles.	2
AC301D.2	Describe the contents of research paper in summarized form.	2
AC301D.3	Apply the techniques learn from research paper in other situations.	3

ST-401: OPTIMIZATION TECHNIQUES

Course Objectives (CObs):

- To understand the basic mathematical concepts of optimization
- To learn various techniques such as Linear and Non-linear, quadratic Programming Problem, Duality in Linear Programming.
- To understand application of optimization techniques in Inventory modelling, Queueing theory etc.
- to formulate and apply techniques for solving business decision problems

- Mathematical Programming Problem. (1L,2M)
- Convex sets and functions. (6L,5M)

  Convex sets, supporting and separating hyper-plane, convex polyhedron, convex functions. Role of convex sets and function in Mathematical programming Problem.
- Linear Programming Problem (LPP). (6L,9M)

  Linear programming models, Graphical solution to LPP, Standard LPP (SLPP), basic solution and basic feasible solution to SLPP. Method for solving LPP: Simplex Algorithm, Two-phase simplex method, Charne's M-technique.
- Duality in LPP. (5L,6M)

  Dual LP, simplex multipliers and their interpretation with reference to dual variables. Duality theorems, Dual simplex method with justification, Post-optimality (sensitivity) analysis, Changes affecting feasibility and optimality.
- Integer LPP (ILPP) (8L,8M)
  - Methods for ILPP: Gomory's algorithm for pure ILPP, branch and bound method.
  - Applications of ILPP.
- Quadratic Programming Problem (QPP). (8L,8M)

  Definition of QPP, Kuhn-Tucker conditions, Algorithms for solving QPP: Wolfe's and Beale's algorithm, Dual of QPP.
- Network Models. (8L,8M)

  Network definitions and applications. Shortest route problem and shortest-route algorithm-Dijkstra's algorithm. Maximal flow model and Maximal flow algorithm, Network representation, critical path computations.
- Probabilistic Inventory Models. (8L,8M)

  General Inventory model, Classic EOQ model-lead time, reorders point, Probabilitized EOQ model. Probabilistic EOQ model, single period model: No setup model and setup model (s-s policy), multiperiod model.
- Queuing Systems. (10L,10M)
  - Elements of queuing models, Role of exponential distribution in queuing models.
  - Classification of queuing models with standard notations.
  - Poisson Queuing models, Generalized Poisson Queuing model and their steady state distributions.
  - Steady state solutions of M/G/1, G/M/1 and M/D/C queuing models using imbedded Markov chain method.

REFERENCES

1. Kambo N. S. (1991) Mathematical Programming Techniques.
2. Hadley G. (1987) Linear Programming.
3. Taha H.A. (2002) Operations Research 6th ed. (Macmillan).
4. Panneerselvam, R. Operations Research (Prentic hall of India)
5. Medhi j. (1984) Stochastic Processes 2nd ed.(New Age International Pvt. Ltd.)

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST401.1	Identify the relationship between decision variable and the objective function with respect to the constraints	2
ST401.2	Explain and solve Linear programming problem using simplex method, dual simplex method and carry out sensitivity analysis of LPP.	3
ST401.3	Apply the concept of Optimization problem, theory of duality, queuing theory, inventory models and networking models in real world problems	3

ST-402: ACTUARIAL STATISTICS

Course Objectives (CObs):

- To make student aware about Indian Insurance business.
- To describe the concept of risk and measurement risk models.
- To describe some basic concepts of Financial Mathematics.
- To explain the role of statistical theory while addressing the problem of finding premium under different life insurance contracts.

- Introduction to Insurance Business. (3L,3M)
- Insurance and utility theory. (4L,4M)
- Risk models for Insurance. (5L,5M)
  - Individual and aggregate Risk models for short term.
  - Distribution of aggregate claims, compound Poisson distribution and its applications. Distribution of aggregate claims, compound Poisson distribution and its applications.
- Survival function and Life tables. (10L,10M)
  - Survival function, Distribution function, Density functions and Force of mortality. Time-until-death random variable and Curtate-future lifetime random variable.
  - Life tables, Select and ultimate life tables.
  - Assumptions for fractional ages and some analytical laws of mortality.
- Life Insurance. (10L,10M)
  - Principles of compound interest: Nominal and effective rates of interest and force of interest and discount, compound interest, accumulation factor, continuous compounding.
  - Insurance payable at the moment of death and at the end of the year of death, level benefit insurance, Whole life insurance, endowment insurance, deferred insurance and varying benefit insurance.
  - Recursion equations and commutation functions.
- Annuities. (10L,10M)
  Annuities certain, Continuous and Discrete life annuities. Life annuities with m-thly payments and approtionable annuities. Recursion equations.
- Net premium. (8L,8M)
  - Fully continuous and discrete premiums.
  - True m-thly payment premiums, apportionable premiums and accumulation type benefits. Insurance model including expenses.
- Reserve. (6L,6M)
  Prospective and retrospective reserve. Fully continuous and discrete net premiums reserves. Reserves on a semicontinuous basis and true m-thly premiums. Reserves on an apportionable or discounted continuous basis. Recursive formulates and differential equations for reserves commutation functions.
- Multiple life functions. (4L,4M)
  Joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws.

REFERENCE

1. Robin Cunningham, Thomas N. Herzog, Richard L. Models for Quantifying Risk, 4th Edition, ACTEX Publications, 2011.
2. Browers, Newton L et al., Actuarial Mathematics 2nd . Society of Actuaries, 1997.

3. Dickson, David C. M., Hardy, Mary R. and Waters, Howard R., Actuarial Mathematics for life contingent risks, International series on actuarial science, Cambridge 2009.
4. Deshmukh S. R., An Introduction to Actuarial Statistics, University Press, 2009
5. Narang, Uma, Insurance Industry in India: Features, Reforms and Outlook, New Century Publications

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST402.1	Identify basic risk available in the problem and formulate suitable loss random variable.	2
ST402.2	Summarize different terms of life tables and their applications in Life Insurance.	2
ST402.3	Apply tools of Financial Mathematics to solve the real-life problems related to investment, loan repayment and life annuities.	3
ST402.4	Simulate data from present value random variables from different life insurances or life annuities to estimate required premium.	3
ST402.5	Formulate new need-based life insurance contract.	6

ST-403: TIME SERIES ANALYSIS

Course Objectives (CObs):

- To Understand the fundamental advantage and necessity of forecasting in various situations, summarize and carry out exploratory and descriptive analysis of time series data, classical decomposition model, different smoothing methods and their advantages and limitations over each other, accuracy measures etc.
- Explain the concepts and basic properties of AR, MA, ARMA and ARIMA models, choosing an appropriate forecasting method in a particular environment of stationarity/non-stationarity.
- Analyzing the frequency domain -Sampling Periodograms, Spectral Density, Identifying the important periodic components of a series, ARCH Models for changing variation and periods of volatility in a series.

- Time series as discrete parameter stochastic process. Auto covariance and autocorrelation functions and their properties. (8L,8M)
- Exploratory Time Series Analysis Tests for trend and seasonally. Exponential and Moving Average Smoothing. Holt and Winters smoothing. Forecasting based on smoothing, Adaptive smoothing. (8L,8M)
- Detailed study of the stationary processes: (1) Moving average (MA), (2) Auto regressive (AR) and (3) ARMA process. Discussions (without proof) of estimation of mean, auto covariance and autocorrelation functions under large sample theory. Partial autocorrelation function. Estimation of Parameters, Choice of AR and MA periods. Order selection for ARMA process, Forecasting ARMA processes, Residual analysis and diagnostic checking. (20L,20M)
- Introduction to spectral analysis of weakly stationary process. Periodogram and correlogram analyses. (6L, 6M)
- Nonstationary and Seasonal Time series Models: Unit-root in nonstationarity, Unit-root tests, Integrated ARMA (ARIMA) models, Box-Jenkins models. Estimation of ARIMA model parameters. Seasonal ARIMA (SARIMA) models (12L, 12M)
- Introduction to Conditional Heteroschedastic Models: Volatility models, ARCH and GARCH, Properties, Examples, Estimation and Forecasting. (6L, 6M)

REFERENCES

1. Box, G.E.P and Jenkins G.M. (1994). Time Series Analysis-Forecasting and Control, Holden-day San Francisco.
2. Anderson. T.W. (1971). The Statistical Analysis of Time Series Wiley, N.Y.
3. Montgemory, D.C. Johnson L.A (1990) Forecasting and Time Series Analysis, McGraw Hill.
4. Kendall, Sir Maurice and Ord, J.K. (1990). Time Series (Third Edition), Edward Arnold.
5. Brockwell, P.J. and Davis R.A.(2006) Time Series: Theory and Methods (Second Edition) Springer-Verlag.
6. Fuller, W.A (1996) . Introduction to Statistical Time series , John Wiley N.Y.
7. Granger, C.W.J. and Newbold (1984) Forecasting Economic Time Series, Third Edition, Academic Press.
8. Kendall, M.G. and Stuart A. (1966). The Advanced Theory of Statistics, Volume 3, Charles Griffing, London.
9. Koopmans, L.H. (1974), The Spectral Analysis of Time series, Academic Press.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST403.1	Outline the processes of identification, estimation and diagnosis of a time series, the criteria for choosing between models and the diagnostic tests that might be applied to the residuals of a time series after estimation	2
ST403.2	Choose appropriate statistical model for modelling the time-series data, assessment of the suitability of the model, use a model for forecasting and determining prediction intervals for forecasts, be aware of limitations and possible sources of errors in the analysis	3
ST403.3	Identify the important periodic components of a series through frequency domain analysis	2

ST-404(A): DATA MINING

Course Objectives (CObs):

- To apply acquired knowledge for understanding data, Data pre-processing and data quality.
- Apply suitable methods for data analysis and algorithms for data mining.

Unit I: (15L)

Supervised Learning**:** Linear methods for classification, linear discriminant analysis (LDA), logistic regression, Bayes classifier, nearest neighbor classifier packages in R for these methods.

Unit II: (15L)

Neural network (NN), support vector machine (SVM) packages in R for these methods.

Unit III: (15L)

Regression and classification trees (CART), Assessment and model selection: Bias variance trade off, training error rate, AIC, BIC, CIC, DIC (information criterion), cross validation Ada boosting.

Unit IV: (15L)

Unsupervised learning: Clustering procedures-k-means, hierarchical, self-organizing map, EM algorithm, feature selection: principal component analysis, association rules, software packages for these methods.

Books Recommended

1. Breiman, L., Friedman, J.H., Olshen, R.A. and Stone, C.J. (1984). Classification and Regression Trees. (Wadsworth and Brooks/Cole).
2. Daniel T.Larose, (2006). Data Mining Methods and Models. Wile-Interscience.

3. Galit Shmueli, Nitin Patel, Peter Bruce, (2010). Data Mining for Business Intelligence: Concepts, Techniques, and Applications in Microsoft Office Excel with XLMiner , Wiley
4. Hastie T., Tibshirani R. and Friedman J. H., (2003). The Elements of Statistical Learning: Data Mining, Inference and Prediction. Springer.
5. Mitchell Tom, (1997). Machine Learning. McGraw-Hill.
6. Ripley, B.D. (1996)..Pattern Recognition and Neural Networks. (Cambridg University Press).

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST404A.1	Analyze data mining problems and reason about the most appropriate methods to apply to a given dataset and knowledge extraction need.	4
ST404A.2	Implement basic pre-processing, association mining, classification and clustering algorithms.	3
ST404A.3	Apply and reflect on advanced pre-processing, association mining, classification and clustering algorithm.	3
ST404A.4	Work efficiently in groups and Evaluate the algorithms on real-world problems.	4

ST-404(B): SURVIVAL ANALYSIS

Course Objectives (CObs):

- To learn the different statistical distributions of survival models
- To understand censored data and non-parametric techniques for survival estimation

Unit I: (15L)

Meaning of censoring, concepts of time, order and random censoring (left and right), survival function, density function, hazard function (rate), cumulative hazard rate, mean residual life function, percentile residual life function, Equilibrium distribution function. Exponential distribution and it's no ageing properties: Lack of memory property, constant failure rate, Cauchy-function equation, constant mean residual life function, TTT transform, identity function as a TTT transform

Ageing classes - IFR, IFRA, NBU, NBUE, DMRL, HNBUE and their duals, and inter relationship among these classes. Bathtub Failure rate, IFRA closure property, bound on reliability function of an IFRA distribution.

Unit II: (15L)

Life distributions - Exponential Gamma, Weibull, Lognormal, Pareto, linear Failure rate, Makeham family, Lehman families (proportional hazard rate family), spacing, normalized spacing and results of an exponential distribution based on normalized spacing.

Parametric inference for complete data:

a) Exponential distribution: Point estimation of parameter of exponential distribution and Fisher information, exact and asymptotic Confidence Intervals for λ, obtaining minimal sufficient and consistent estimator of λ, Graphical method for checking exponentiality of data.
b) Weibull: Obtaining MLE of scale and shape parameter of Weibull distribution and sample information matrix.
c) Gamma: Obtaining MLE of scale and shape parameter of Gamma distribution and sample information matrix.
d) Lognormal: Obtaining MLE of of parameter μ and σ, Confidence Interval for μ and σ

Unit III: (15L)

Parametric inference for censored data:

a) Type I censoring: Exponential distribution
b) Type II censoring: Exponential, gamma, Lognormal
c) Random censoring: Exponential, Lehman family, Weibull distribution,

Non-Parametric estimation of survival Function

a) For complete data: Non-parametric estimator of distribution function and survival function, distribution of empirical survival function, confidence band for survival function (by Using Kolmogorov - Smirnov statistics)
b) For censored data: Actuarial estimator of survival Function, Estimator of variance of actuarial estimator (Greenwoods formula), product limit estimator and its variance, redistribution to right algorithm.

Unit IV: (15L)

Test for Exponentiality: Estimable function of degree r, Kernel, symmetric Kernel, U-statistic, variance of U- Statistic, one sample U-Statistic theorem, Hollander and Proschan Test, Test for exponentiality against positive ageing based n sample spacing, Analytical test for exponentiality against NBUE, Deshpande's Test, Two sample U statistic theorem, Wilcoxon and Mann –Whitney test, Gehan's test, Mantel- Haenzel test, Log rank test, Semi-parametric regression for failure rate Cox's proportional hazards model with one and several covariates.

REFERENCES

1. Cox, D.R. and Oakes, D. (1984) Analysis of Survival Data, Chapman and Hall, New York.
2. Deshpande, J.V, Purohit, S. G.,(2005),Life Time Data :Statistical Models and Methods
3. Elandt - Johnson, R.E., Johnson N.L. (1980) Survival models and Data Analysis, John Wiley and Sons
4. Gross A.J. and Clark, V. A. (1975) Survival Distributions: Reliability Applications in the Biomedical Sciences, John Wiley and Sons.
5. Miller, R.G. (1981) Survival Analysis (Wiley)

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST404B.1	Understand various statistical methods and Data Analysis techniques for Survival models.	2
ST404B.2	Apply parametric and non-parametric methods for estimation of survival Function.	3
ST404B.3	Estimate parameters when lifetime data available for censored observations.	5

ST-405: TECHNICAL COMMUNICATIONS AND PRACTICALS-IV

Course Objectives (CObs):

- To make students aware of some soft skills for technical communication and preparation for interviews.
- To handle data sets on life tables, financial mathematics, life insurance contracts.
- To estimate parameters and function of parameters of different lifetime distributions.
- To fit different models to time series data using R, to study the role of diagnostic tests that might be applied to the residuals of the fitted time series model and study the criteria for choosing between models.
- To formulate and solve optimization problems.

Technical Communications (24Hrs, 40 marks Internal Evaluation)

Each student will have to prepare his/her presentation/lecturer based on any topic from Statistics and deliver / present it before all students and teachers of the department.

Practicals-IV (66 Hrs, 60 marks External Practical Examination)

(Based on software and computer programming)

A. Practicals based on course Actuarial Statistics (22 Hrs,20M)

1. Calculation of simple interest and compound interest.
2. Relation between nominal, effective and force of interest.
3. Plotting of utility functions.
4. Distribution of total claim in short term risk models.
5. Construction of life tables and Problems based on life tables
6. Life table using analytical laws of mortality.
7. Annuity immediate and due.
8. Calculation of premiums.
9. Calculation of reserves.
10. Multiple life functions.

B. Practicals based on course Time Series Analysis (22 Hrs,20M)

1. Exploratory Analysis.
2. Smoothing.
3. Numerical exercises on MA and AR models Forecasting.

4. Numerical exercises on ARMA and ARIMA models Forecasting.
5. Numerical exercises on Box-Jenkins models.
6. Residual analysis and diagnostic checking.
7. Periodogram analysis and interpretation.
8. Correlogram analysis and interpretation.
9. Numerical exercises on Non-Stationary time series models
10. Volatility models.

C. Practicals based on course Data Mining (22 Hrs, 20M)

Concerned teacher is expected to design the practicals according to the syllabus.

OR

Practicals based on course Survival Analysis (22 Hrs, 20M)

Concerned teacher is expected to design the practicals according to the syllabus.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST405.1	Prepare self seminar presentation, CV and write official letters/mails for communication.	3
ST405.2	Fit suitable model to time series data and justify its appropriateness through accuracy measures or different criteria such as AIC, AICC or BIC.	3
ST405.3	Apply knowledge of life tables, financial mathematics, human mortality laws to calculate premium of life insurance contracts.	3
ST405.4	Solve different optimization related problems using statistical software.	6
ST405.5	Simulate and Understand queuing and inventory process	2

ST-406: PROJECT

Course Objectives (CObs):

- The intention of the project work is to make students develop a little deeper knowledge and understanding in the context of a specific topic.
- The overall objective is to enable students think independently on a specific topic, design and perform a set of experiments to display the knowledge and capability required for independent work.
- It also aims at managing time effectively while working independently, appropriate referencing, analyzing the results and develop skills in report writing.

- Project duration: 10th December to 31st March. Students are supposed to submit final project report by April 10.
- Project Guide: Teachers from the Department of Statistics and/or personnel from organization where student is going to visit for field work or training. Each project group will be guided by concerned teacher (guide) for one hour per week throughout the semester.
- Fieldwork: Students will be given one month period in December during last semester for their industrial work/data collection/survey or any other fieldwork involved in the project.
- Project Topic: Students in consultation with the guide will decide Project Topic/Area. Topic may be decided after completion of third semester. Project work may be carried out in a group of students depending upon the depth of fieldwork/problem involved.
- Project report: Project report should be submitted in typed form with binding by 10th April. Project viva will be arranged during April 15-20.
- Project evaluation: Project evaluation will be based on
  - Evaluation by Guide (40 Marks)
  - External Examination (60 Marks)
    - Project report(20 Marks)
    - Presentation by student or group of students. (20 Marks)
    - Viva voce (20 marks)
    - Two examiners will evaluate project work.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
ST406.1	Understand the real-world problems through statistical angle.	2
ST406.2	Design and execute experiments/surveys independently.	6
ST406.3	Analyze, co-relate and interpret the data and build up skills and temperament of scientific writing.	4

AUDIT COURSES: SEMESTER-IV

AC-401(A): Human Rights

Course Objectives (CObs):

To make students aware about human rights and human values

Unit 1 **Introduction to Human Rights** **6 hrs.**

1.1 Concept of Human Rights
1.2 Nature and Scope of Human Rights
1.3 Fundamental Rights and Fundamental Duties
1.4 Interrelation of Rights and Duties

Unit 2 **Human Rights in India** **8 hrs.**

2.1 Meaning and Significance of **:**
1) Right to Equality 2) Right to Freedom, 3) Right against Exploitation, 4) Right to Freedom of Religion, 5) Cultural and Educational Rights, and 6) Right to Constitutional Remedies.
2.2 Constitutional Provisions for Human Rights
2.3 Declaration of Human Rights
2.4: National Human Rights Commission

Unit 3 **Human Values** **8 hrs.**

3.1: Meaning and Definitions of Values
3.2: Importance of values in the life of Individual
3.3: Types of Values
3.4: Programmes for conservation of Values

Unit 4 **Status of Social and Economically Disadvantaged people and their rights** **8 hrs.**

4.1: Rights of women and children in the context of Social status
4.2: The Minorities and Human Rights
4.3: Status of SC/ST and other Indigenous People in the Indian Scenario
4.4: Human rights of economically disadvantaged Society

Suggested readings:

1. Human rights education – YCMOU, Nasik
2. Value education – SCERT, Pune
3. Human rights reference handbook – Lucille whare

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC401A.1	Practice the learned issues under human rights and human values in real life.	3
AC401A.2	Provide social justices to people around them and provide guidance about human rights to their friends, parents and relatives.	

AC-401(B): Current Affairs

Course Objectives (CObs):

To make students updated about current affairs of India and world

	Title	Content	Hours
Unit 1	Politics & Economy	• National & International Political Activity, Organization. • Economy & Business, Corporate world	08
Unit 2	Awards and recognitions	• National & International Awards and recognitions • Books and authors	07
Unit 3	Science & Technology	• Software, Automobile, Space Research • New inventions and discoveries	07
Unit 4	Environment & Sports	• Summit & conference, Ecology & Climate, Organization. • National & International Games, Olympics, commonwealth etc.	08

Suggested readings (Use recent years' data and current literature):

1. India 2019, by Publications Division Government of India
2. Manorama Year Book by Philip Mathew,
3. India 2019, Rajiv Maharshi
4. Quick General Knowledge 2018 with Current Affairs Update, Disha Experts
5. General Knowledge 2018: Latest Who's Who & Current Affairs by RPH Editorial Board.

Course Outcomes (COts):

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

Course Outcome	Course Outcome	Cognitive Level
AC401B.1	Identify important issues currently/ recently happening in India or world.	2
AC401B.2	Summarize current affairs regularly	2

AC-401(C): INTRODUCTION TO LaTeX

Course Objectives (CObs):

- Learn basics of LaTex, Syntax,
- Apply various packages of LaTex for article/report writing etc.
- Apply beamer for presentations, book writing etc.

- Installation of LaTeX (1L)
- Basic Syntax, Mathematical Equations, Matrices, Tables (2L)
- Page Layout–Titles, Abstract, Chapters, Sections, References, Equation references, citation (3L)
- List making environments: Table of contents, generating new commands, Figure numbering, List of figures, List of tables, Generating index (4L)
- Packages: Geometry, Hyperref, amsmath, amssymb, color, tilez, listing etc. (4L)
- Classes: article, book, report, beamer, slides etc. (6L)
- Writing Resume, question paper, articles/research papers (6L)

- Bibliographies and graphics (2L)
- Presentation using beamer (2L)

REFERENCES

1. Kottwitz, Stefan. *LaTeX beginner's guide*, Packt Publishing Ltd, 2011.
2. Grätzer, George. *Math into LATEX,* Springer Science & Business Media, 2013.
3. Mittelbach, Frank, et al. *The LATEX companion*, Addison-Wesley Professional, 2004.
4. Kottwitz, Stefan. *LaTeX Cookbook*, Packt Publishing Ltd, 2015.

Note: Each student is required to submit a report/article prepared by using LaTeX.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
AC401C.1	Apply basic components of LaTeX along with accessing different packages from MikTex such as package manager, update manager, etc.	3
AC401C.2	Write mathematical articles/documents via LaTeX.	3
AC401C.3	Prepare presentation using Seminar and Beamer Package.	6

AC-401(D): HISTORY OF STATISTICS

Course Objectives (CObs):

- To motivate students to learn about history of subject statistics.
- To know about historical Indian/International statisticians and their contribution.
- To gain information about well-known statistical institutes and their contribution.

Students are expected to learn

- History of Statistical Concepts (3L)
- History of Statistical data collection and data keeping (3L)
- History of Statisticians and their contribution (3L)
- Contribution of Historical Indian Statisticians (3L)
- History of International Statistical Institutes (3L)
- History of Indian Statistical System (3L)
- History of Statistical Software (3L)
- Report preparation of any aspect of History of Statistics (9L)

Note: Each student is required to submit a report/article prepared on any aspect of history of Statistics.

REFERENCES

1. Stigler, Stephen M. *The history of statistics: The measurement of uncertainty before 1900*. Harvard University Press, 1986.
2. Bernstein, Peter L., and Peter L. Bernstein. *Against the gods: The remarkable story of risk*. New York: Wiley, 1996.
3. Rao, T. J. "Official Statistics in India: The past and the present." *Journal of Official Statistics* 26.2 (2010): 215.
4. Ghosh, Jayanta K., et al. "Evolution of statistics in India." *International Statistical Review/Revue Internationale de Statistique* (1999): 13-34.

Course Outcomes (COts):

After completing this course, the student will be able to:

Course Outcome	Course Outcome	Cognitive Level
AC401D.1	Describe historical development of statistical theory/concepts.	2
AC401D.2	Collect and report contribution of different National/International statisticians.	2
AC401D.3	Compare National/International statistical systems.	3

List of Equivalent Courses

Course Code	Title of the Course under old Syllabus (w.e.f. 2015-16)	Course Code	Title of Equivalent Course under New Syllabus (w.e.f. 2019-20)
ST-101	Real Analysis	ST-101	Real Analysis
ST-102	Linear Algebra	ST-102	Linear Algebra
ST-103	Sample Survey and Statistics for National Development	ST-103	Sampling Theory and Statistics for National Development
ST-104	Distribution Theory	ST-104	Distribution Theory
ST-105	Computer Programming in C++ and Numerical Methods	-	#
ST-106	Practicals- I	ST-106	Practicals- I
ST-201	Probability Theory	ST-201	Probability Theory
ST-202	Stochastic Processes	ST-304	Stochastic Processes
ST-203	Multivariate Analysis	ST-203	Multivariate Analysis
ST-204	Parametric Inference	ST-204	Parametric Inference
ST-205	Linear Models and Regression Analysis	ST-202	Linear Models and Regression Analysis
ST-206	Practicals-II	ST-206	Practicals-II
ST-301	Asymptotic and Nonparametric Inference	ST-301	Asymptotic and Nonparametric Inference
ST-302	Design, Planning and Analysis of Experiments	ST-302	Design, Planning and Analysis of Experiments
ST-303	Total Quality Management (TQM) and Statistical Process Control (SPC) and Reliability	ST-303	Total Quality Management (TQM) and Statistical Process Control (SPC) and Reliability
ST-304(A)	Design and Analysis of Clinical Trials	ST-305(A)	Design and Analysis of Clinical Trials
ST-304(B)	Financial Mathematics	-	#
ST-305	Practicals-III	ST-306	Practicals-III
ST-401	Optimization Techniques	ST-401	Optimization Techniques
ST-402	Actuarial Statistics	ST-402	Actuarial Statistics
ST-403(A)	Time Series Analysis	ST-403	Time Series Analysis
ST-403(B)	Statistical Simulations	-	#
ST-404	Technical Communications and Practicals-IV	ST-405	Technical Communications and Practicals-IV
ST-405	Project	ST-406	Project
MS-001 (CBCS)	Statistical Methods and Mathematical Reasoning	-	#
-	-	ST-105	R Programming and Numerical Methods
-	-	AC-101	Practicing Cleanliness$
-	-	ST-205	Python Programming
-	-	AC-201(A)	Soft Skills
-	-	AC-201(B)	Practicing Sports Activities
-	-	AC-201(C)	Practicing Yoga
-	-	AC-201(D)	Introduction to Indian Music
-	-	ST-305(B)	Econometrics
-	-	AC-301(A)	Computer Skills
-	-	AC-301(B)	Cyber Security
-	-	AC-301(C)	Base Statistical Analysis Software (SAS)
-	-	AC-301(D)	Review of Research Paper
-	-	ST-404(A)	Data Mining
-	-	ST-404(B)	Survival Analysis
-	-	AC-401(A)	Human Rights
-	-	AC-401(B)	Current Affairs
-	-	AC-401(C)	Introduction to LaTeX
-	-	AC-401(D)	History of Statistics

No equivalent courses available for these papers, so student may be allowed to appear by old courses.