University of Kalyani

Department of Statistics

STRUCTURE AND DETAILED CURRICULUM FOR
SEMESTER-BASED
5-Year Integrated M. Sc. Course in Statistics
(Under NEP-2020)

With Effect from 2026-27

COURSE STRUCTURE

T: Theory, Pr: Practical, Tu: Tutorial
MJ: Major, SEC: Skill Enhancement Course, DSE: Discipline Specific Elective,
MP: Minor Project, RP: Research Project

5-Year Integrated M. Sc. in Statistics: SEMESTER 1

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-101	Calculus-I	T+Tu	4	40	10	10	60
5-ST-MJ-102	Higher Algebra	T+Tu	4	40	10	10	60
5-ST-MJ-103	Descriptive Statistics I	T+Pr	4	40	10	10	60
5-ST-MJ-104	Probability I	T+Tu	4	40	10	10	60
Total			16	160	40	40	240

5-Year Integrated M. Sc. in Statistics: SEMESTER 2

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-201	Calculus-II	T+Tu	4	40	10	10	60
5-ST-MJ-202	Linear Algebra	T+Pr	4	40	10	10	60
5-ST-MJ-203	Descriptive Statistics II	T+Pr	4	40	10	10	60
5-ST-MJ-204	Probability II	T+Pr	4	40	10	10	60
5-ST-SEC-205	Data Management	T+Pr	4	40	10	10	60
Total			20	200	50	50	300

5-Year Integrated M. Sc. in Statistics: SEMESTER 3

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-301	Calculus-III	T+Tu	4	40	10	10	60
5-ST-MJ-302	Univariate Sampling Distribution	T+Tu	4	40	10	10	60
5-ST-MJ-303	Numerical Analysis	T+Pr	4	40	10	10	60
5-ST-MJ-304	Vital Statistics and Demography	T+Pr	4	40	10	10	60
Total			16	160	40	40	240

5-Year Integrated M. Sc. in Statistics: SEMESTER 4

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-401	Multivariate Analysis	T+Pr	4	40	10	10	60
5-ST-MJ-402	Economic Statistics and Indian Statistical System	T+Pr	4	40	10	10	60
5-ST-MJ-403	Parametric Estimation	T+Pr	4	40	10	10	60
5-ST-MJ-404	Testing of Hypothesis	T+Pr	4	40	10	10	60
5-ST-SEC-405	C++ Programming	Pr	4	0	50	10	60
Total			20	160	90	50	300

5-Year Integrated M. Sc. in Statistics: SEMESTER 5

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-501	Linear Models	T+Tu	4	40	10	10	60
5-ST-MJ-502	Large Sample Theory	T+Tu	4	40	10	10	60
5-ST-MJ-503	Sampling Techniques	T+Pr	4	40	10	10	60
5-ST-MJ-504	Time Series Analysis	T+Pr	4	40	10	10	60
5-ST-SEC-505	R Programming	Pr	4	0	50	10	60
Total			20	160	90	50	300

5-Year Integrated M. Sc. in Statistics: SEMESTER 6

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ -601	Regression Analysis	T+Pr	4	40	10	10	60
5-ST-MJ -602	Linear Programming and Game Theory	T+Pr	4	40	10	10	60
5-ST-MJ -603	Sequential Analysis and Nonparametric Inference	T+Pr	4	40	10	10	60
5-ST-MJ -604	Experimental Design	T+Pr	4	40	10	10	60
5-ST-MJ -605	Statistical Quality Control	T+Pr	4	40	10	10	60
5-ST-MP -606	Internship / Minor Project	Pr	4	0	50	10	60
Total			24	200	100	60	360

5-Year Integrated M. Sc. in Statistics: SEMESTER 7

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-701	Real Analysis	T+Tu	4	40	10	10	60
5-ST-MJ-702	Measure Theory and Probability	T+Tu	4	40	10	10	60
5-ST-MJ-703	Sampling Distribution	T+Tu	4	40	10	10	60
5-ST-MJ-704	Stochastic Process	T+Pr	4	40	10	10	60
5-ST-MJ-705	Sample Survey	T+Pr	4	40	10	10	60
Total			20	200	50	50	300

5-Year Integrated M. Sc. in Statistics: SEMESTER 8

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-801	Asymptotic Theory	T+Tu	4	40	10	10	60
5-ST-MJ-802	Theory of Estimation	T+Pr	4	40	10	10	60
5-ST-MJ-803	Theory of Hypothesis Testing	T+Pr	4	40	10	10	60
5-ST-MJ-804	Decision Theory	T+Pr	4	40	10	10	60
5-ST-MJ-805	Nonparametric Methods	T+Pr	4	40	10	10	60
5-ST-MJ-806	Design of Experiments	T+Pr	4	40	10	10	60
Total			24	240	60	60	360

5-Year Integrated M. Sc. in Statistics: SEMESTER 9

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-SEC-901	Research Methodology & IKS	T+Tu	4	40	10	10	60
5-ST-MJ-902	Advanced Regression Analysis	T+Pr	4	40	10	10	60
5-ST-MJ-903	Reliability and Life Testing	T+Pr	4	40	10	10	60
5-ST-MJ-904	Operations Research	T+Pr	4	40	10	10	60
5-ST-SEC-905	Python Programming	Pr	4	0	50	10	60
Total			20	160	90	50	300

5-Year Integrated M. Sc. in Statistics: SEMESTER 10

Paper Code	Paper Name	T + (Pr/Tu)	Credit	Marks Distribution			Total
				Theory	Pr/Tu	Internal	
5-ST-MJ-1001	Multivariate Techniques	T+Pr	4	40	10	10	60
5-ST-MJ-1002	Artificial Intelligence and Machine Learning	T+Pr	4	40	10	10	60
5-ST-DSE-1003	To be offered from the list	T+Pr	4	40	10	10	60
5-ST-DSE-1004	To be offered from the list	T+Pr	4	40	10	10	60
5-ST-RP-1005	Project	Pr	8	0	100	20	120
Total			24	160	140	60	360

Semester 1

5-ST-MJ-101 Calculus-I (Marks-60, Credit-4)

Real number system: Number system, set, relation, mapping.

Real sequences: Limit points of a sequence, convergent sequences, divergent sequences, monotonic sequences, algebra of convergent sequences, limit superior and limit inferior, Cauchy sequences.

Series of real numbers: Convergence of a series, positive term series. Alternating series: conditional and absolute convergence, rearrangement of series. Test of absolute convergence: comparison test, Cauchy's root test, D'Alembert's ratio test, Cauchy's integral test. Power series.

Functions of one variable: limit, continuity, algebra on limits and of continuous functions. Continuity of composite functions.Properties of continuous functions on closed intervals.Uniform continuity.

Derivative: differential, chain rule, meaning of the sign of a derivative at a point, Rolle's theorem, Mean value theorems with Lagrange and Cauchy, Taylor's theorem with Lagrange's and Cauchy's form of remainder [Maclaurin's series, expansions of cos x, sin x, e^x, $(1+x)^m$ and log (1+x)], Local maxima and minima.

References:

1. Das, B.C. and Mukherjee, B.N.: Differential Calculus.
2. Goldberge, R.R (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
3. Malik, S.C. and Arora, S. (2008): Mathematical Analysis, New Age International (P) Ltd.
4. Chakraborty, Arnab: Real Analysis, Vol-1.

5-ST-MJ-102 Higher Algebra (Marks – 60, Credit – 4)

Complex numbers: Argand plane, modulus and argument of complex numbers, properties of moduli and amplitudes of complex numbers. Principal value of arguments, complex conjugate, Imaginary cube roots of unity. De Moivre's theorem and its applications, exponential, sine, cosine, logarithmic, inverse circular and hyperbolic functions of a complex variable.

10 L

Theory of Equations: Division algorithm (without proof), Remainder theorem, synthetic division, Application of Remainder theorem, Fundamental theorem of classical algebra (without proof) and its consequences, Multiple roots. Statement and application of Descartes' rule of signs. Relation between roots and coefficients, symmetric functions of roots, Transformations of polynomial equations, Cardan's solution of the cubic equation. Some standard algebraic inequalities. 12L

Determinants: General definition and properties of a determinant, minors and cofactors. Evaluation of different types of determinants by reducing to a similar form,r^{th} order minor and its algebraic complement. Laplace expansion. 6L

Set theory: Sets, finite and infinite sets, subsets and power sets of a set, equality, union, intersection, complement, difference and symmetric difference of sets. Basic laws for union and intersection of sets. De Morgan's law. Ordered pair, Cartesian product of two sets. Binary relation in a set, equivalent relation, partition, injective, surjective and bijective mapping, identity mapping, inverse of a mapping, composition of mappings. 8L

Groups, Rings and Fields: Groups, semi-groups, Abelian and non-Abelian group, identities in groups, uniqueness of identity and inverse of an element in a group. Subgroups and their characterization, Invariance of identity and inverse of an element in subgroups. Finite groups, composition table, order of a group, order of an element in a group, Notion of Cyclic groups. Definition and examples of rings, integral domains and fields. 12L

References:

1. Das & Mukherjee: Higher Algebra.
2. Mapa, S.K.: Higher Algebra (Classical).
3. Das and Basu: Algebra.
4. Lahiri, B.K. & Ray, K.C. – Higher Algebra.

5-ST-MJ-103 Descriptive Statistics I (Marks: 60, Credit: 4)

Introduction, Types, Collection and Scrutiny of Data : Nature, definition and scope of Statistics; uses of Statistics; Statistics in relation to other disciplines; abuses and limitations of Statistics; concepts of individual, population and sample; census and sample survey; observational and experimental studies; types of data—primary and secondary, qualitative and quantitative, cross-sectional and time-series, discrete and continuous, frequency and non-frequency data; scales of measurement—nominal, ordinal, interval and ratio; methods of data collection; designing questionnaires and schedules; scrutiny of data for internal consistency and detection of errors; missing data—nature, sources and basic imputation methods; major sources of secondary data. 12 L

Presentation of Data : Compilation and tabulation of data; construction of statistical tables with one or more factors of classification; diagrammatic representation of data including simple, multiple and sub-divided bar diagrams, pie diagrams; frequency and cumulative frequency distributions; graphical representation through histogram, frequency polygon and ogives; stem-and-leaf display; box plot. 12 L

Descriptive Measures for Univariate Data: Measures of central tendency—Arithmetic Mean, Median and Mode; measures of dispersion—Range, Mean Deviation, Standard Deviation and Coefficient of Variation; relative concentration—Gini's Coefficient and Lorenz Curve; moments (raw and central), measures of skewness and kurtosis; statement of Sheppard's correction for moments; Lyapunov's inequality and other moment inequalities; quantiles including quartiles, deciles and percentiles and measures based on them; identification of outliers using box plot; numerical problems related to measures of location, dispersion, relative dispersion, skewness and kurtosis. 24 L

References

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. I, 8th Edition, The World Press, Kolkata.
2. Freedman, D., Pisani, R. and Purves, R. *Statistics*. W. W. Norton & Company.
3. Moore, D. S. and Notz, W. I. *Statistics: Concepts and Controversies*.
4. Siegel, A. F. and Morgan, C. J. *Statistics and Data Analysis: An Introduction*.
5. Wallis, W. A. and Roberts, H. V. *Statistics: A New Approach*.
6. Yule, G. U. and Kendall, M. G. *An Introduction to the Theory of Statistics*.
7. Kendall, M. G. and Stuart, A. *The Advanced Theory of Statistics*, Vol. I.
8. Tukey, J. W. *Exploratory Data Analysis*. Addison-Wesley Publishing Company.
9. Agresti, A. *An Introduction to Categorical Data Analysis*. John Wiley & Sons.

5-ST-MJ-104 Probability I (Marks – 60, Credit – 4)

Random Experiment, Sample point, Sample space, Event, classical definition of probability and limitations, statistical regularity and meaning of probability, probability by relative frequency, related exercises. 14L

Operation on events, field of events, Kolmogorov's axiomatic definition of probability, detailed discussion on discrete space only. 10L

Results on probability on union and intersection of events, conditional probability, independence, Bayes' theorem and its applications. Related exercises, Geometric probability. 12L

Random variable, cumulative distribution function (cdf) of a random variable and its properties, probability mass function (pmf) and probability density function (pdf), expectation, variance, moments, quantiles, moments generating function (mgf) and probability generating function (pgf), Markov's and Chebyshev's inequality. 12L

References:

1. Feller W. (1968): An Introduction to Probability Theory & its Applications, John Willy.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B: Fundamentals of Statistics, Vol. 1- World Press.
3. Goon, A.M., Gupta, M.K. & Dasgupta, B: An Outline of Statistical Theory, Vol. 1- World Press.
4. Rohatgi, V.K. (1984): An Intro to Prob. Theory and Mathematical Statistics, John Wiley.
5. Hoel, P.J., Port, S.C. & Stone, C.J.: Introduction of Probability Theory (Vol-I) Houghton Mifflin & UBS.
6. Mukhopadhyay, P.: Theory of Probability.
7. Uspensky, J.V. (1937): Introduction to Mathematical Probability, McGraw Hill.

Semester 2

5-ST-MJ-201 Calculus-II (Marks-60, Credit-4)

Indefinite integral as a reverse process of differentiation, evaluation of some standard indefinite integrals, Reimann's definition and existence of the integral, elementary properties. Integrability of continuous functions.The fundamental theorem of integral calculus. Reduction formulae for

$$\int_0^{\pi/2} \sin^n x\,dx,\ \int_0^{\pi/2} \cos^n x\,dx,\ \int_0^{\pi/2} \sin^n x \cos^m x\,dx,\ \int_0^{\pi/2} \tan^n x\,dx$$

Improper integrals: Notions of improper integrals. Beta and Gamma functions (convergence assumed), their mutual relations and elementary properties.

Sequence and series of functions: point-wise convergence, uniform convergence and absolute convergence, simple tests of convergence.

Evaluation of simple plane areas, arc lengths, volumes and surfaces of solids of revolution.

References:

1. Das, B.C. and Mukherjee, B.N.: Differential Calculus.
2. Goldberge, R.R (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
3. Malik, S.C. and Arora, S. (2008): Mathematical Analysis, New Age International (P) Ltd.
4. Chakraborty, Arnab: Real Analysis, Vol-2.

5-ST-MJ-202 Linear Algebra (Marks – 60, Credit – 4)

Vectors: Finite-dimensional vector space over a field of real numbers, addition and scalar multiplication of vectors, linear combination and linear independence, linear span.Subspaces, union, intersection, sum and direct sum of subspaces. Basis, dimension, related results. Norm of a vector. Inner product, Euclidean space, orthogonality and orthonormality, Gram –Schmidt process. 18L

Matrices: Linear transformations and matrices, various types of matrices, matrix operations, elementary operations, elementary matrices, transpose of matrix, symmetric matrix. Row space, column space, rank of a matrix,null space and nullity, and related results. Determinant of a square matrix, inverse of a matrix, trace, orthogonal matrix. Partitioned matrix and its inverse, reduction of a matrix to a normal form. Echelon form. Homogeneous and non-homogeneous system of linear equations, consistency, related results. Characteristic equation of a matrix, eigenvalues and eigenvectors, simple related results regarding real symmetric matrices. Quadratic forms,classification of quadratic forms, Canonical reduction, spectral decomposition.

30L

References:

1. A. Ramachandra Rao, P Bhimasankaram: Linear Algebra.

2. Hadley. G: Linear Algebra.
3. Chatterjee, B.C.: Linear Algebra.
4. Chakraborty, Arnab: Linear Algebra.
5. Goon A.M.: Vectors and Matrices.

5-ST-MJ-203 Descriptive Statistics II (Marks: 60, Credit: 4)

Bivariate Data and Correlation: Bivariate data; scatter diagram; simple (product-moment) correlation coefficient and its properties; concept of regression; principle of least squares; simple linear regression; fitting of polynomial and exponential curves; intra-class correlation coefficient (equal and unequal group sizes); correlation ratio; correlation index and related inequalities; rank correlation—Spearman's rank correlation coefficient and Kendall's tau (including tie cases). 20 L

Analysis of Categorical Data: Contingency tables; consistency of categorical data; independence and association of attributes; measures of association for two-way classified data; odds ratio; relative risk; Pearson's measure of association; Goodman–Kruskal's Gamma. 12 L

Scaling of Data : Motivation for scaling; types of scales—nominal, ordinal, interval and ratio scales; measurement of psychological traits; scaling of items according to difficulty; scaling of test scores; scaling of rates and ranks; scaling of judgements. 8 L

Fitting of Theoretical Distributions :Fitting of Binomial, Poisson and Normal distributions. 8 L

References

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. II, 7th Edition, The World Press, Kolkata.
2. Mukhopadhyay, P. *Applied Statistics*. Books and Allied (P) Ltd., Kolkata.
3. Agresti, A. *Analysis of Ordinal Categorical Data*. John Wiley & Sons.
4. Guilford, J. P. and Fruchter, B. *Fundamental Statistics in Psychology and Education*. McGraw-Hill.
5. Siegel, A. F. and Morgan, C. J. *Statistics and Data Analysis: An Introduction*.
6. Wallis, W. A. and Roberts, H. V. *Statistics: A New Approach*.
7. Lewis-Beck, M. S. (Ed.). *Regression Analysis*.

5-ST-MJ-204 Probability II (Marks – 60, Credit – 4)

Standard univariate discrete distributions: degenerate, discrete uniform, Bernoulli, Binomial, hypergeometric, Poisson, geometric, negative binomial with their properties, related exercises. 16L

Standard univariate continuous distributions: rectangular, normal, Cauchy, gamma, beta, exponential, lognormal, Pareto, logistic, log-logistic, Weibull distributions and their properties. 18L

Bivariate probability distributions, marginal and conditional distributions, covariance, correlation coefficient, conditional expectation and variance, bivariate normal distribution and its properties. 14L

References:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B: An Outline of Statistical Theory, Vol. 1- World Press.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B: Fundamentals of Statistics, Vol. 1- World Press.
3. Rohatgi, V.K. (1984): An Introduction to Probability Theory and Mathematical Statistics, John Wiley.
4. Johnson, N. L., Kotz, S., & Balakrishnan, N. (1994). *Continuous Univariate Distributions,*Vol. 1- John Wiley &Sons.
5. Johnson, N. L., Kotz, S., & Balakrishnan, N. (1980).*Univariate Discrete Distributions,* John Wiley &Sons.
6. Mukhopadhyay, P: Theory of Probability.

5-ST-SEC-205 Data Management (Marks: 60, Credit: 4)

Computer Fundamentals: Introduction to computers; characteristics and applications of computers; computer hardware and software; operating systems; memory units and storage devices; number systems and data representation; computer networks and the Internet; computer security, cyber safety and basic cloud computing concepts. 8 L

Database Management Systems: Concept and overview of Database Management Systems (DBMS); advantages of DBMS; data models; database languages; database administrator and database users; three-schema architecture of DBMS.

Entity–Relationship Model: basic concepts, mapping constraints, keys, E-R diagrams, weak entity sets and extended E-R features.

Relational Model: structure of relational databases, relational algebra, relational calculus, views and database modification.
SQL: DDL, DML and DCL commands; basic SQL queries; set operations; aggregate functions; NULL values; domain constraints; referential integrity; assertions; views; nested subqueries; introduction to stored procedures and triggers.
Functional dependency; anomalies in database design; normalization (1NF, 2NF, 3NF, BCNF, 4NF and 5NF); decomposition; transaction processing; concurrency control; serializability; lock-based protocols; two-phase locking; file organization; indexing using B-tree and B+ tree.
18 L

Statistical Data Analysis using Microsoft Excel:Introduction to Microsoft Excel interface and workbook management; data entry, formatting, sorting and filtering; conditional formatting; formulas and statistical functions; data validation and data cleaning; frequency distributions; graphical presentation of data using bar charts, pie charts, histograms, scatter plots and line charts; descriptive statistics using Excel Data Analysis ToolPak; computation of measures of central tendency, dispersion, skewness and kurtosis; quartiles, percentiles and box plots; correlation and simple linear regression; fitting of Binomial, Poisson and Normal distributions; Pivot Tables, Pivot Charts and preparation of statistical reports and dashboards. 12 L

Statistical Data Analysis using Jamovi: Introduction to Jamovi and its interface; importing, managing and transforming datasets; data visualization; descriptive statistics; frequency tables and cross-tabulations; graphical presentation; correlation analysis; simple linear regression; generation and interpretation of statistical outputs; preparation of statistical reports.
10 L

References

1. Balagurusamy, E. Fundamentals of Computers. McGraw-Hill Education.
2. Thareja, R. Computer Fundamentals and Programming in C. Oxford University Press.
3. Silberschatz, A., Korth, H. F. and Sudarshan, S. Database System Concepts. McGraw-Hill.
4. Ramakrishnan, R. and Gehrke, J. Database Management Systems. McGraw-Hill.
5. Elmasri, R. and Navathe, S. B. Fundamentals of Database Systems. Pearson.
6. Majumdar, A. K. and Bhattacharya, P. Database Management Systems. Tata McGraw-Hill.
7. Walkenbach, J. Microsoft Excel Bible. Wiley.
8. Alexander, M. and Kusleika, D. Excel 365 Bible. Wiley.
9. Navarro, D. J. and Foxcroft, D. R. Learning Statistics with Jamovi. Jamovi Project.
10. Jamovi User Guide. Jamovi Project. Available at https://www.jamovi.org

Semester 3

5-ST-MJ-301 Calculus III (Marks – 60, Credit – 4)

Functions of several variables: Notions of partial derivatives of implicit functions, chain rules, total differential and derivatives of implicit functions. Simple counter example to fxy =fyx. Schwarz's theorem on the equality (Statement only), Euler's theorem on homogeneous functions of two variables (problems up to three variables). Lagrange's method of multipliers for extreme (working rules only). 14L

Multiple integrals, transformations and Jacobians (Statement and examples), polar and orthogonal transformations, Dirichlet's integral. 14L

Differential equations: Genesis of ordinary differential equations. First order linear and non-linear equations. Exact equations, use of integrating factors, First order and higher degree equations. Clairaut's form, singular solution. Second and higher order linear equations with constant coefficients. Euler's homogeneous equations. Simultaneous linear equations of first and second order. 16L

References:

1. Das, B.C. and Mukherjee, B.N. : Differential Calculus, U. N. Dhur & Sons Ltd.
2. Das, B.C. and Mukherjee, B.N. :Integral Calculus Differential Equations U. N. Dhur & Sons Ltd.
3. Goldberge, R.R (1970): Methods of Real Analysis. Oxford & IBH Publishing Co.
4. Malik, S.C. and Arora, S (2008): Mathematical Analysis, New Age International (P) Ltd.
5. Shanti Narayan and Mittal, P.K. (2004): A course of Mathematical Analysis. S. Chand & Co. Ltd.

5-ST-MJ-302 Univariate Sampling Distribution (Marks – 60, Credit – 4)

Concept of random sampling, statistic and sampling distribution of statistics. Different methods for finding sampling distribution of a statistic. Derivation of the distribution of the sample total related to binomial and Poisson populations and conditional distribution of a single observation given the total. 8L

Distribution of the sum of two i.i.d. rectangular variables and sum & ratio of two independent gamma variables and sum of two independent beta variables. 10L

Distribution of linear function of independent normal variables, ratio of two independent normal variables, central χ^2, t & F distributions. Definitions of non-central χ^2, t and F. 10L

Sampling distributions of mean and variance of a random sample from a normal population. 4L

Sampling distributions of means, variance and correlation coefficient of a random sample from a bivariate normal population. Distribution of sample regression coefficient for both stochastic and non-stochastic regressors. 12L

Distribution of sample order statistic from a continuous population, distribution of sample range and quantiles. 4L

References:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory, Vol. 2.
2. Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics.
3. Rohatgi& Saleh: An Introduction to Probability and Statistics.
4. Hogg, R.V. & Craig, A.T.: Introduction to Mathematical Statistics.
5. Mukhopadhyay, P.: Mathematical Statistics.
6. Rao, C.R.: Linear Statistical Inference and its application.

5-ST-MJ-303 Numerical Analysis (Marks-60, Credit-4)

Approximation of number and functions, Absolute and relative errors, Δ & E operators, related problems on separation of symbols.

Interpolation Formulae: Newton's forward, Newton's backward, Lagrange's formulae.

Divided Difference operator, Newton's divided difference formula. Central interpolation formulae by Stirling and Bessel.

Subtabulation, Inverse interpolation.

Numerical differentiation and its applications.

Numerical Integration: Quadrature formula. Trapezoidal, Simpons' 1/3 rd and 3/8th rules with error terms.

Numerical solution of equation in one unknown.Regula-falsi, bisection, iterative, Newton-Raphson methods.Condition of convergence.

References:

1. Scaborough, J.B.: Numerical Analysis.
2. Jain, M.K. Iyenger, S. R. K. & Jain, R. K.: Numerical Methods for Scientific and Engineering Computation, New age International.
3. Saxena, H.C.: The Calculus of Finite Differences, S.Chand& Com., New Delhi.
4. Goon, A.M., Gupta, M.K. & Dasgupta, B,: Fundamentals of Statistics, Vol-1- World Press, Kolkata.
5. Freeman, H (1962): Finite Differences for Actuarial Students, CambridgeUniversity Press.
6. Kalyan Mukherjee: Numerical Analysis.

5-ST-MJ-304 Vital Statistics & Demography (Marks: 60, Credit: 4)

Introduction and Sources of Demographic Data: Introduction to Vital Statistics and Demography; sources of demographic data—census, civil registration system, ad hoc sample surveys and hospital records; demographic profile of the Indian Census; errors in census and registration data and their adjustment; measurement of population, rates and ratios of vital events. 10 L

Measurement of Mortality, Fertility and Morbidity: Measurement of mortality—Crude Death Rate (CDR), Age-Specific Death Rate (ASDR), Standardized Death Rate (SDR), Cause-Specific Death Rate, Infant Mortality Rate (IMR), Maternal Mortality Rate (MMR), Central Mortality Rate and Force of Mortality; measurement of fertility—Crude Birth Rate (CBR), General Fertility Rate (GFR), Age-Specific Fertility Rate (ASFR), Total Fertility Rate (TFR), Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR); measurement of morbidity. 14 L

Life Tables and Population Models: Complete life table—assumptions, description, construction, main features and uses; national life tables and United Nations model life tables; abridged life tables and their construction by Chiang's method; graduation of mortality rates by Gompertz's and Makeham's laws; stable and stationary populations. 14 L

Population Growth, Migration and Population Projection: Measurement of population growth—crude rate of natural increase, Pearl's Vital Index; internal and international migration, net migration and migration models; population estimation and projection by arithmetic progression and geometric progression methods; intercensal and postcensal population estimates;

logistic curve fitting for population forecasting by Pearl–Reed and Rhodes methods; population interpolation by Reed–Merrell, Greville's and King's methods. 10 L

References:

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics, Vol. II*. The World Press, Kolkata.
2. Misra, B. D. *An Introduction to the Study of Population.* South Asian Publishers Pvt. Ltd., New Delhi.
3. Mukhopadhyay, P. *Applied Statistics*. Books and Allied (P) Ltd., Kolkata.
4. Biswas, S. Demography.
5. Shryock, H. S., Siegel, J. S. and Associates. *The Methods and Materials of Demography*. Academic Press.
6. Keyfitz, N. and Caswell, H. *Applied Mathematical Demography*. Springer.
7. Preston, S. H., Heuveline, P. and Guillot, M. Demography: *Measuring and Modeling Population Processes*. Blackwell Publishing.

Semester 4

5-ST-MJ-401 Multivariate Analysis (Marks-60, Credit-4)

Descriptive measures on multivariate data: multiple correlation, partial correlation, relationship between higher order and lower order partial correlations, related problems and inequalities.

Multivariate Probability Distribution: Mean vector and covariance matrix, marginal and conditional distribution, ellipsoid of concentration, multiple regression, multiple correlation, partial correlation.

Standard Multivariate Probability Distributions: Multivariate normal, multinomial, Dirichlet distributions, their properties and related results.

References:

1. Anderson, T.W.: An Introduction to Multivariate Analysis (Chapter-2), John Wiley.
2. Gun, A.M. Gupta, M.K. &Dasgupta, B.: Fundamentals of Statistics, Vol-1 (Chapter-II), World Press, 2002.

3. Kendall, M.G. & Stuart, A: Advanced Theory of Statistics, Vol 1 (Ch. 15), Vol (Ch-26, 27), Charles Griffin.
4. Gun, A.M. Gupta, M.K. &Dasgupta, B.: an outline of Statistical Theory, Vol-1, World Press, 2003.
5. Rao, C.R.: Linear Statistical Theory and its Applications (Chapter-4 &8), Wiley Eastern, 1974.
6. Wilks, S.S.: Mathematical Statistics (Chapter 6 &&) John Wiley.

5-ST-MJ-402 Economic Statistics and Indian Statistical System (Marks: 60, Credit: 4)

Index Numbers: Price, quantity and value index numbers; problems in the construction of index numbers; Laspeyres', Paasche's, Edgeworth–Marshall's and Fisher's Ideal index numbers; chain base index numbers; tests of consistency of index numbers—time reversal, factor reversal and circular tests; Consumer Price Index (CPI) and Wholesale Price Index (WPI)—methods of construction, uses and limitations. 12 L

Demand Analysis and Consumer Behaviour: Theory and analysis of consumer demand; law of demand; price elasticity of demand; income elasticity of demand; Engel curves—forms and properties; estimation of Engel curves from family budget data using the weighted least squares method. 12 L

Official Statistical System in India : The Indian Statistical System; National Statistical Office (NSO), Ministry of Statistics and Programme Implementation (MoSPI), State Directorates/Bureaux of Economics and Statistics with special reference to West Bengal; major official statistical sources relating to population, agriculture, industry, trade, prices, employment and national income; Census of India, Sample Registration System (SRS), National Sample Surveys (NSS), Annual Survey of Industries (ASI), Economic Census and Periodic Labour Force Survey (PLFS); National Income Statistics; official statistics and Sustainable Development Goals (SDGs); open government data, statistical quality, confidentiality and ethics in official statistics. 24 L

References

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. II. The World Press, Kolkata.
2. Mukhopadhyay, P. *Applied Statistics*. Books and Allied (P) Ltd., Kolkata.
3. Prais, S. J. and Houthakker, H. S. *The Analysis of Family Budget Data*. Cambridge University Press.
4. Kendall, M. G. and Stuart, A. *The Advanced Theory of Statistics*, Vol. III.

5. Allen, R. G. D. *Index Numbers in Theory and Practice*. Macmillan Press.
6. Saluja, M. P. *Indian Official Statistics*. Statistical Publishing Society, Kolkata.
7. Ministry of Statistics and Programme Implementation (MoSPI). *Statistical Year Book India*.
8. Ministry of Statistics and Programme Implementation (MoSPI). *National Statistical System in India*.
9. Government of India. *Economic Survey* (Latest Edition).

5-ST-MJ-403 Parametric Estimation (Marks – 60, Credit – 4)

Data reduction: Sufficiency, factorization theorem (Proof in discrete case only), Exponential family. 6L

Point estimation: Properties of estimators, mean square error (MSE) and minimum MSE estimator, unbiasedness and minimum variance unbiased estimators (MVUE), Rao-Cramer lower bound and related results, Rao-Blackwell theorem, relative efficiency of an estimator, Fisher's information. 16L

Consistency, notion of asymptotic efficiency Methods of estimation: method of moments, method of maximum likelihood (excluding proofs of large sample properties), method of minimum chi-square, method of least-squares. 12L

Basic concepts of Bayes' estimation: prior and posterior distributions, posterior mean as an estimator of the parameter, application to simple examples on Bernoulli, normal etc. 8L

References:

1. Goon, Gupta and Dasgupta: An Outline of Statistical Theory, Vol.2.
2. Rohatgi, V. K. & Saleh, A.K.M.E.: An Introduction to Probability Theory and Mathematical Statistics, 2nd Ed.
3. Mukhopadhyay, P.: Mathematical Statistics.
4. Rao, C.R.: Linear Statistical Inferences and its Applications.
5. Hogg and Craig: Introduction to Mathematical Statistics.
6. Mood, A. M., Graybill, F. A. and Boes, D. C. (1974): Introduction to the Theory of Statistics, McGraw Hill and Kogakusha.
7. Casella, G., & Berger, R. (2024). *Statistical inference*. CRC press.

5-ST-MJ-404 Testing of Hypothesis (Marks – 60, Credit – 4)

Simple and composite, two types of errors, level of significance, p-value, size of a test, power of a test, unbiased tests. Most powerful (MP), uniformly most powerful (UMP) and uniformly most powerful unbiased (UMPU) tests, Randomized and nonrandomized tests, Fundamental Neyman-Pearson (NP) Lemma (Proof of sufficiency part only) and its use in the construction of MP and UMP test (single parameter with range independent of parameter), Power curve. 18L

Exact test of significance relating to binomial, Poisson and normal parameters. 12L

Likelihood Ratio (LR) tests, its applications in connection with univariate normal and for the equality of means and variances of several univariate normal populations. 8L

Interval estimation: Confidence intervals and confidence sets, confidence coefficient, confidence intervals for the parameters of univariate normal, difference of means of two independent homoscedastic normal distributions. 10L

References:

1. Goon, Gupta and Dasgupta: An Outline of Statistical Theory, Vol.2 .
2. Rohatgi & Saleh: An Introduction to Probability Theory and Mathematical Statistics, 2nd Ed.
3. Mukhopadhyay, P.: Mathematical Statistics.
4. Rao, C.R.: Linear Statistical Inferences and its Applications.
5. Kale, B. K.: Parametric Inference.
6. Santhakumaran, A.: Fundamentals of Testing Statistical Hypotheses.
7. Hogg and Craig: Introduction to Mathematical Statistics,
8. Mood, A. M., Graybill, F. A. and Boes, D. C.: Introduction to the Theory of Statistics.

5-ST-SEC-405 C++ Programming (Marks-60, Credit-4)

Basics of C++ language: Input / Output Statements, Control Structures.

Functions: Library functions, user-defined functions, functions declaration.

Pointers: manipulation of pointers data.

Applications to some statistical problems.

Monte Carlo Simulation.

Computer work.

References:

1. Balagurusamy: Object Oriented Programming with C++, McGraw Hill.
2. Lippman, S. B., Lajoie, J. and Moo, B. E.: C++ Primer, Pearson
3. Kernighan and Ritchie: The C Programming Language.
4. KanetkarYashavant : Let Us C++, BPB Publication

Semester 5

5-ST-MJ-501 Linear Models (Marks – 60, Credit – 4)

Gauss-Markov Set-up: Linear models, Linear parametric function, Methods of least squares, Gauss-Markov theorem, estimability and BLUE, estimation space and error space.Statement of Fisher-Cochran Theorem. Estimation of error variance, SS due to Linear functions of observations, canonical forms, F-statistic in connection with the general linear hypothesis. 16L

Analysis of Variance (ANOVA): Fixed, random and mixed effect models. One-way classified data (fixed and balanced random effect), two-way classified data with equal number of observations per cell (fixed, random and mixed). 16L

Regression Analysis: Testing related to simple regression model, multiple regression model. 8L

Analysis of covariance:Analysis of covariance with one concomitant variable in one-way and two-way classified data. 8L

References:

1. Kshirsagar, A.M.: Linear Models.
2. Searle: Linear Statistical Methods.
3. Rao, C.R.: Linear Statistical Inference and its Applications.
4. Goon A.M., Gupta M.K.: Das Gupta. B.: An Outline of Statistical Theory, Vol.2.
5. Scheffe, H.: The Analysis of Variance.

5-ST-MJ-502 Large Sample Theory (Marks – 60, Credit – 4)

Notion of convergence in probability and in law, statement of Slutsky's theorem, Chebyshev's WLLN, Central Limit Theorem (CLT), use of CLT for deriving large sample tests for binomial proportions, difference of two binomial proportions, mean of a population and difference of means of two independent populations. Related confidence intervals. 16L

Large sample standard error; derivation of large sample standard error of a function of statistics in the multiparameter situation, sample moments, standard deviation, coefficient of variation, b_1 and b_2 measures and correlation coefficient. Uses of these standard errors in large sample tests and interval estimation. Test of normality. 16L

Transformation of statistics to stabilize variance: derivations of Sin^{-1}, square-root, logarithmic and z-transformation and their uses in large sample tests and interval estimation. 6L

Derivation of the large sample distribution of Pearsonian χ^2 statistic and its uses in test of independence, homogeneity and goodness of fit. 4L

References:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B : An Outline of Statistical Theory, Vol. 1, World Press, Kolkata.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B : An Outline of Statistical Theory, Vol. 2, World Press, Kolkata.
3. E. L. Lehmann: Elements of Large Sample Theory, Springer.
4. Rao, C.R.: Linear Statistical Inference and its Applications.
5. Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics, John Wiley.

5-ST-MJ-503 Sampling Techniques (Marks: 60, Credit: 4)

Introduction to Sampling: Concepts of population and sample; need for sampling; complete enumeration versus sample survey; planning and execution of sample surveys; analysis and

reporting of survey data; sampling and non-sampling errors; sources of bias and methods of minimizing bias; probability and non-probability sampling techniques including judgement and purposive sampling; random numbers and their use in sample selection; introduction to snowball sampling. 12 L

Basic Sampling Designs: Simple Random Sampling With and Without Replacement (SRSWR and SRSWOR); selection procedures; unbiased estimation of population mean, total and proportion; variances and estimation of variances (standard errors); determination of sample size; stratified random sampling—technique, estimation of population mean and total, variances, proportional and optimum allocation, comparison with simple random sampling, post-stratification; systematic sampling (linear and circular)—selection procedure, estimation of population mean and total, comparison with simple random sampling and stratified sampling. 16 L

Advanced Sampling Methods: Cluster sampling (equal-sized clusters); two-stage sampling with equal-sized primary sampling units under SRSWOR at each stage; estimation of population mean and total, variances and optimum choice of sampling and sub-sampling fractions; concept of sub-sampling; Probability Proportional to Size Sampling with Replacement (PPSWR); interpenetrating sub-sampling technique for unbiased variance estimation and its applications. 12 L

Ratio, Regression and Sensitive Surveys: Ratio and regression methods of estimation; estimation of population mean and total; mean square error and comparison with simple random sampling; double sampling for ratio and regression estimators; Randomized Response Technique—Warner's model. 8 L

References

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. II. The World Press, Kolkata.
2. Cochran, W. G. *Sampling Techniques*, 3rd Edition. Wiley.
3. Murthy, M. N. *Sampling Theory and Statistical Methods*. Statistical Publishing Society, Kolkata.
4. Des Raj and Chandhok, P. *Sample Survey Theory*. Narosa Publishing House.
5. Mukhopadhyay, P. *Theory and Methods of Survey Sampling*. Prentice Hall of India.
6. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S. and Asok, C. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics.

5-ST-MJ-504 Time Series Analysis (Marks-60, Credit-4)

Economic time series, different components, additive and multiplicative models, determination of trend, by moving average and mathematical curve fitting, Variate difference method, Slutsky-Yule effect, analysis of seasonal fluctuation, construction of seasonal indices. Dummy Variable method

Stationary Time Series – Weak stationary, definition of Auto Regression (AR), Moving Average (MA) processes, ARMA Process; Discrimination between AR(1), AR(2), MA(1) and MA(2) processes by Correlogram analysis. Sample autocorrelation, ACF, PACF and their graphical use in guessing the order of AR and MA processes, Estimation of parameters of AR(1) and AR(2) processes using Yule-Walker equations, Parameter estimation for MA and AR and ARMA process

Idea of Non-stationary time series, Locally non-stationary series, ARIMA model, Volatility, ARCH and GARCH process (basic ideas only)

Forecasting: Exponential smoothing and Holt-Winter's method, Brown's discounted regression, Box-Jenkins model.

References:

1. Goon, A.M., Gupta, M.K. &Dasgupta, B: Fundamentals of Statistics, Vol. II-World Press, Kolkata.
2. Kendall M.G. (1976): Time Series, Charles
3. Brockwell and Davis (2010): Introduction to Time Series and Forecasting (Springer Texts in Statistics), 2nd Edition.
4. Chatfield, C. (1980): The Analysis of Time Series – An Introduction, Chapman & Hall.
5. G. E. P. Box & G. M. Jenkins :Time Series Analysis– Forecasting and control

5-ST-SEC-505 R Programming (Marks – 60, Credit – 4)

Basics of R programming, numerical arithmetic, simple manipulation of vectors, descriptive statistics on univariate data,bivariate data, factors, descriptive statistics. Arrays and matrices, matrix operations. Lists and data frames, attach, detach,adding a new column, removing a column, adding a new row. Data import and export, read.csv, readxl, read.table, scan; accessing data sets from other R packages. Sorting and ordering, finding indices using 'which()' function,

subsetting a data, using "dplyr" package, merging data frames. Functions in R, for loop and while loop, conditional statements. 24L

Probability distributions, Q-Q plots, K-S tests, one- and two-sample tests. Statistical models in R; Formulae for statistical models, linear model generic functions for extracting model information, ANOVA, updating fitted models, GLM, NLS, maximum likelihood models. Graphical procedures, high-level and low-level plotting commands, graphical parameters. Standard packages from R; some nonstandard statistical models. 24L

References:

1. Gardener, M (2012) Beginning R: The Statistical Programming Language.
2. A simple introduction to R by Arnab Chakraborty
(freely available at http://www.isical.ac.in/~arnabc/)
3. An Introduction to R; manual from www.r-project.org

Semester 6

5-ST-MJ-601 Regression Analysis (Marks – 60, Credit – 4)

Classical General Linear Regression Model (CLRM): Specification, Estimation, Testing, and Interval Estimation of OLS estimators. 12L

Heteroscedastic disturbance: Consequences on OLS estimation, WLS. Tests for heteroscedasticity. Estimation and testing in CLRM with heteroscedastic disturbance. 8L

Autocorrelated disturbance: Consequences on OLS estimation,tests for autocorrelation. Estimation and testing in CLRM with autocorrelated disturbance. 4L

Transformations – Box-Cox models, detection of outliers and influential observations. Dummy variable. 8L

Multi-collinearity (MC): Effect of exact and near-exact MC estimation and testing of regression parameters, VIF. 6L

Regression Diagnostics, variable selection, stepwise regression, best subset, model selection.10L

References:

1. Johnston, J.: Econometric Methods.
2. Johnston & Dinardo: Econometric Methods.
3. Montgomery, D.C., Peck, E.A. & Vinning, G.G.: Introduction to Linear Regression Analysis.
4. Maddala, G.S.: Introduction to Econometrics.

5-ST-MJ-602 Linear Programming & Game Theory (Marks – 60, Credit – 4)

Linear programming: Introduction, statement and formulation of LPP, graphical solution in simple cases. Preliminary mathematics: separating hyper-plane theorem (statement only), Convex sets. 12L

Slack and surplus variables, feasible solutions, standard form and canonical form, fundamental theorem of linear programming and allied results, simplex method and simplex algorithm, artificial variable technique, two-phase method and method of penalties. 16L

Game theory: Introduction: 2 person zero-sum games, pure and mixed strategies, existence of solution and uniqueness of value in zero sum games. LP formulation of a 2 person zero sum game and its solution for m x m case. 18L

References:

1. Chakravarty and Ghosh: Linear Programming and Game Theory
2. Gass: Linear Programming.
3. Hadley. Linear Programming.
4. Kambo N.S.: Mathematical Programming Techniques.

5-ST-MJ-603 Sequential Analysis & Non-parametric Inference (Marks-60, Credit-4)

Sequential Analysis: Need for sequential inference, Wald's SPRT with illustrations, Determination of boundaries approximately, Expression for OC and ASN functions (without proof) of tests regarding parameters of binomial, Poisson and normal distributions.

Nonparametric Inference: Need for nonparametric inference, sample median and interquartile range as point estimates of location and dispersion, distribution-free interval estimation of population quantile, tolerance interval, sign test, Wilcoxon signed-rank test, Mann-Whitney test, run test, median test and tests based on Kendall's t and Spearman's rank correlation coefficient, test of randomness.

References:

1. Goon, A.M., Gupta, M.K. & Dasgupta, B : An Outline of Statistical Theory, Vol. 1, World Press, Kolkata.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B (2001): Fundamentals of Statistics, Vol. 2, World Press.
3. Rao, C.R.: Linear Statistical Inference and its Applications.
4. Goon, A.M., Gupta, M.K. & Dasgupta, B (2001): Fundamentals of Statistics, Vol. 1, World Press.
5. Rohatgi, V.K.: An Introduction to Probability Theory and Mathematical Statistics, John Wiley.
6. Rohatgi, V. K.: Statistical Inference, John Wiley.
7. Gibbons, J.: Nonparametric Statistical Inference, Dekker.

5-ST-MJ-604 Experimental Design (Marks: 60, Credit: 4)

Introduction and Basic Principles of Experimental Design: Role and historical development of Design of Experiments; basic terminologies; experimental error; principles of experimental design—randomization, replication and local control; uniformity trials; fertility contour maps; choice of size and shape of plots and blocks. 10 L

Standard Experimental Designs: Completely Randomized Design (CRD), Randomized Block Design (RBD) and Latin Square Design (LSD)—layout, linear model, assumptions, analysis of variance, estimation of treatment effects and relative efficiencies; comparison of efficiencies of standard designs; analysis of experiments with one missing observation in RBD and LSD. 18 L

Different types of Experimental Designs: Split Plot Design and Strip Plot Design (Strip Arrangement)—layout, linear model and analysis of variance; group of experiments using Randomized Block Design (RBD). 10 L

Factorial Experiments: Advantages of factorial experiments; factorial experiments; main effects and interaction effects; confounding in factorial experiments; total and partial confounding; construction and analysis of and factorial experiments with confounding. 10 L

References

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. II. The World Press, Kolkata.
2. Mukhopadhyay, P. *Applied Statistics*. Books and Allied (P) Ltd., Kolkata.
3. Kempthorne, O. *The Design and Analysis of Experiments*. Wiley.
4. Das, M. N. and Giri, N. C. *Design and Analysis of Experiments*. Wiley Eastern Ltd.
5. Montgomery, D. C. *Design and Analysis of Experiments*. John Wiley & Sons.
6. Cochran, W. G. and Cox, G. M. *Experimental Designs*. John Wiley & Sons.
7. Dey, A. *Theory of Block Designs*. Wiley Eastern Ltd.

5-ST-MJ-605 Statistical Quality Control (Marks: 60, Credit: 4)

Introduction to Quality and Process Control: Concept of quality and quality control; dimensions of quality; quality assurance and quality management; quality systems and ISO quality standards; process control and product control; statistical basis of Statistical Process Control (SPC); seven basic tools of SPC; chance and assignable causes of variation; process capability and process optimization. 10 L

Control Charts for Process Monitoring : General theory of control charts; rational subgrouping; control limits and out-of-control criteria; control charts for variables—-chart, R-chart, S-chart and -chart; modified control charts for means; control charts for attributes—p-chart, np-chart, c-chart and u-chart; comparison of control charts for variables and attributes; Average Run Length (ARL); Moving Average (MA) control charts; Exponentially Weighted Moving Average (EWMA) control charts; Cumulative Sum (CUSUM) control charts using V-Mask and Decision Interval procedures. 18 L

Acceptance Sampling Plan: Principles of acceptance sampling; single and double sampling plans by attributes; Operating Characteristic (OC) curve; Average Outgoing Quality (AOQ); Average Outgoing Quality Limit (AOQL); Average Sample Number (ASN); Average Total Inspection (ATI); Lot Tolerance Percent Defective (LTPD); Dodge–Romig sampling inspection plans; acceptance sampling by variables under one-sided and two-sided specification limits. 14 L

Process Capability and Economic Design: Process capability indices; economic design of -control charts; control by gauging; applications of Statistical Quality Control in manufacturing and service industries. 6 L

References

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. *Fundamentals of Statistics*, Vol. II. The World Press, Kolkata.
2. Mukhopadhyay, P. *Applied Statistics*. Books and Allied (P) Ltd., Kolkata.
3. Montgomery, D. C. *Introduction to Statistical Quality Control*. John Wiley & Sons.
4. Duncan, A. J. *Quality Control and Industrial Statistics*. Taraporevala& Sons.
5. Montgomery, D. C. and Runger, G. C. *Applied Statistics and Probability for Engineers*. Wiley.
6. Hoyle, D. *ISO Quality Systems Handbook*. Butterworth-Heinemann.
7. Ehrlich, B. H. *Transactional Six Sigma and Lean Servicing*. St. Lucie Press.

Semester 7

5-ST-MJ-701 Real Analysis (Marks-60, Credit-4)

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

Real valued functions. Limit, continuity and uniform continuity, Differentiability of univariate and multivariate functions. Mean value Theorems, Extreme of functions.

Riemann Integral. Improper integrals. Riemann – Stieltjes integral. Sequence and series of functions, uniform convergence, Power series, Taylor's Series.

Convex functions and related properties

References:

1. Apostol, T.M. (1985): Mathematical Analysis, Narosa.
2. Rudin, W. (1976): Principles of Mathematical Analysis, McGraw Hill.
3. Goldberg, R.R.: Methods of Real Analysis.

5-ST-MJ-702 Measure Theory and Probability (Marks-60, Credit-4)

Classes of sets, Fields, Sigma fields, Minimum Sigma field, Borel Sigma field in R, Sequence of sets, lim sup and lim inf of a sequence of sets. Measure, Probability Measure, Properties of a measure.

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

Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated Convergence Theorem.

Sequence of random variables, Almost sure convergence.

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

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

Product measure and Fubini's theorem (Statements only)

References:

1. A.K. Basu: Measure Theory & Probability.
2. B.R. Bhat: Modern Probability Theory.
3. P. Billingley: Probability & Measure.
4. J.F.C. Kingman & S.J. Taylor: Introduction to Measure and Probability.
5. R.G. Laha& V.K. Rohatgi : Probability Theory.
6. R. Ash: Real Analysis and Probability.
7. C.W. Burrill: Measure Theory & Probability
8. K.R. Parthasarathi: Introduction to Probability and Measure.

5-ST-MJ-703 Sampling Distribution (Marks – 60, Credit – 4)

Non-central chi-square, t and F distributions. 6L

Distribution of quadratic forms. 2L

Fisher-Cochran's Theorem and related results. 4L

Random sampling from Np (μ,Σ), MLE's of μ and Σ and their stochastic independence. 4L

Central Wishart distribution using Bartlett's decomposition and its properties with proofs. 8L

Distribution of Hotelling's T^2 and Mahalanobis D^2 with applications. 4L

Distribution of sample multiple correlation coefficient. 4L

Distribution of partial correlation coefficient. 4L

Distribution of regression coefficient vector. 4L

References:

1. Rao, C.R.: Linear Statistical Inference and its Applications, Wiley.

2. Anderson, T.W.: Introduction to Multivariate Analysis.

3. Kshirsagar, A.M.: Multivariate Analysis.

4. Srivastava, M.S. and Khatri, C.G.: Introduction to Multivariate Statistics.

5-ST-MJ-704 Stochastic Process (Marks – 60, Credit – 4)

Introduction to Stochastic processes, classification of Stochastic processes according to state space and time domain, Markov chain with finite and countable state space, n-step transition probability and its limit, Chapman – Kolmogorov equation, Stationary distribution classification of states, Random Walk and gambler's ruin problem. 16L

Discrete state space continuous time Markov chain: Poisson process, birth and death process. 12L

Renewal Theory: Elementary renewal theory, statement and uses of key renewal theorem. 8L

Branching process: Galton – Watson branching process, probability of ultimate extinction. 8L

Continuous process: Brownian motion. 4L

References:

1. J. Medhi: Stochastic Processes.
2. S.M. Ross: Introduction to Probability Models.
3. Karlin and Taylor: A First Course in Stochastic Processes.
4. Hoel, Port & Stone: Introduction to Stochastic Processes.

5-ST-MJ-705 Sample Survey (Marks: 60, Credit: 4)

Concepts of sampling design, sampling scheme and sampling strategy; inclusion probabilities; Horvitz–Thompson estimator of population total and mean; unequal probability sampling with and without replacement; Probability Proportional to Size (PPS) sampling; Hansen–Hurwitz estimator; mean per distinct unit estimator under SRSWR; Des Raj estimator; Murthy's estimator and underlying principle; Rao–Hartley–Cochran sampling scheme; Hartley–Ross unbiased ratio estimator. 16 L

Sampling and sub-sampling of clusters; two-stage sampling with unequal numbers of second-stage units; ratio estimation in two-stage sampling; double sampling for stratification; double sampling for ratio and regression estimation; sampling on successive occasions; introduction to small area estimation. 12 L

Non-response in sample surveys; Hansen–Hurwitz callback method; Politz–Simmons' not-at-home method; randomized response techniques for qualitative and quantitative sensitive characteristics. 10 L

Variance estimation under unequal probability sampling; comparison of unequal probability estimators; symmetrized Des Raj estimator; efficiency considerations in advanced sampling designs; applications of advanced sampling methods in official statistics and large-scale national sample surveys. 10 L

References

1. Cochran, W. G. *Sampling Techniques*. Wiley.
2. Des Raj. *Sampling Theory*. McGraw-Hill.
3. Murthy, M. N. *Sampling Theory and Methods*. Statistical Publishing Society, Kolkata.
4. Mukhopadhyay, P. *Theory and Methods of Survey Sampling*. Prentice Hall of India.
5. Chaudhuri, A. and Mukerjee, R. *Randomized Response: Theory and Techniques*. Marcel Dekker.
6. Chaudhuri, A. and Stenger, H. *Survey Sampling: Theory and Methods*. Marcel Dekker.
7. Sinha, B. K. and Hedayat, A. S. *Design and Inference in Finite Population Sampling*. Wiley.
8. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S. and Asok, C. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics.

Semester 8

5-ST-MJ-801 Asymptotic Theory (Marks – 60, Credit – 4)

Review of different modes of convergence, Scheffe's theorem, Slutsky's theorem. Characteristic function of random vector and the Multivariate CLT, Cramer Wold Device, δ-method of deriving the asymptotic distribution of a smooth function of an asymptotically normal sequence. Law of large numbers, Law of iterated logarithm. 20L

Sample statistics: Empirical distribution function (edf), strong consistency, asymptotic distribution of the edf. 6L

Quantiles: Consistency and asymptotic normality. Bahadur's representation of sample quantiles. 6L

Order Statistics: Relation to quantiles, asymptotic distribution of extreme order statistics. 6L

L-Statistic: Consistency and asymptotic normality due to Stigler (1974). 6L

Sample spacings: Uniform spacings, exponential spacings, general continuous spacings and extreme spacings. 4L

References:

1. P. Billingsley: Probability and Measure, Wiley.
2. C.R. Rao: Linear Statistical Inference and its Applications, Wiley.
3. R.J. Serfling: Approximation Theorems on Mathematical Statistics, Wiley.
4. S.S. Wilks: Mathematical Statistics, Wiley.
5. B. R. Bhatt: Modern Probability Theory, New Age International Publishers
6. E. L. Lehmann: Elements of Large Sample Theory, Springer.
7. T. S. Ferguson: A First Course in Large Sample Theory.
8. T. K. Chandra: A First Course in Asymptotic Theory of Statistics.
9. AW van der Vaart: Asymptotic Statistics.

5-ST-MJ-802 Theory of Estimation (Marks – 60, Credit – 4)

Sufficiency minimal Sufficiency, Factorization theorem in the dominated case (without proof), completeness, ancillary statistic, Basu's theorem. Unbiased estimation, Lehmann-Scheffe theorem, Chapman-Robbins inequality, Rao-Cramer Lower bound in the multiparameter case (statement only), Bhattacharyya inequality. 16L

Equivariant estimation with emphasis on location and scale, minimum risk equivariant estimators, Pitman estimator. 8L

Large sample considerations: consistency of estimators, consistency of the minimum likelihood estimator under Cramer type conditions, asymptotic normality of the one-step MLE, method of scoring (including the multiparameter set–up in all cases), asymptotic efficiency, Hodges' example, Bahadur's theorem on supper – efficient estimators (without proof). 12L

Resampling procedures in the context of estimation: the jackknife and bootstrap. 6L

Concept of robustness, Influence function and M-estimators. 6L

References:

1. Goon A.M., Gupta M.K., and Dasgupta, B.: An Outline of Statistical Theory, Vol 2, World Press.
2. Lehmann, E.L. and Casella, G.:Theory of Point Estimation, 2nd Ed, John Wiley.
3. Rao, C. R. (1973): Linear Statistical Inference & its Applications, Wiley. 12
4. Shao, J and Tu, D. (1995): The Jack Knife and Bootstrap, Springer.
5. Hampel, F., Ronchetti, E., Rousseeuw, P., & Stahel, W. (1986). Robust Statistics: The Approach based on Influence Functions. John Wiley & Sons, New York.

5-ST-MJ-803 Theory of Hypothesis Testing (Marks-60, Credit-4)

Neyman-Pearson lemma, monotone likelihood ratio property, one-sided hypothesis against a one sided alternative, generalized Neyman-Pearson lemma (without proof), two sided hypothesis in a one parameter exponential family, least favourable distributions.

Locally best test (One sided), similar test, Neyman structure, UMPU test for a one-parameter exponential family.

Likelihood Ratio test (LRT), Asymptotic distribution of LRT statistics under simple null hypothesis (real parameter only), Wald's test and Rao's score test, consistency of the LR test for simple hypothesis, Bartlett's test for homogeneity of variances.

Confidence sets: relation with hypothesis testing; optimum confidence intervals.
Sequential tests, SPRT and its properties, fundamental identity, OC and ASN, Wald's equation for ASN.

References:

1. Lehmann, E.L.: Testing Statistical Hypotheses.
2. Ferguson, T.S.: Mathematical Statistics-A Decision Theoretic Approach.
3. Rohatgi, V.: An Introduction to Probability and Mathematical Statistics.
4. Rao, C.R.: Linear Statistical Inference and its Applications.
5. Kendall, M.G. and Stuart, A.: The Advanced Theory of Statistics, Vol. II.
6. Goon, A.M., Gupta M.K. and Dasgupta, B.: An Outline of Statistical Theory, Vol II.

5-ST-MJ-804 Decision Theory (Marks: 60, Credit: 4)

Elements of statistical decision problems; states of nature, action space, loss function, risk function and decision rules; randomized and non-randomized decision rules; statistical games and two-person zero-sum games; point estimation and hypothesis testing as decision problems; admissible decision rules; complete, essentially complete, minimal complete and minimal essentially complete classes of decision rules; completeness based on sufficient statistics; Rao–Blackwell theorem (statement only). 12L

Prior, likelihood and posterior distributions; Bayes risk and Bayes decision rules; extended Bayes rules, generalized Bayes rules and limit of Bayes rules; risk set, lower boundary set ; admissibility of Bayes rules; minimax rules and computation of minimax rules; relation between admissible, Bayes and minimax rules; separating hyperplane theorem (statement only); existence and completeness of the class of Bayes rules; computation of minimax tests for one-sided hypotheses in monotone likelihood ratio (MLR) families. 16L

Classical and Bayesian approaches to statistical inference; prior, likelihood and posterior distributions; conjugate and non-informative priors; Bayesian point estimation under common loss functions; posterior risk; credible intervals (introductory concepts); posterior predictive distributions; illustrative examples of one-parameter models using conjugate priors. 12L

Decision-theoretic approaches to point estimation, hypothesis testing and classification problems; comparison of classical and Bayesian decision procedures; Bayesian decision rules in estimation and testing; applications of decision theory in reliability, quality control and medical decision making. 8L

References

1. Ferguson, T. S. *Mathematical Statistics: A Decision Theoretic Approach*. Academic Press.
2. Berger, J. O. *Statistical Decision Theory and Bayesian Analysis*. Springer.

3. Lehmann, E. L. *Theory of Point Estimation*. Springer.
4. Robert, C. P. *The Bayesian Choice: From Decision-Theoretic Foundations to Computational Implementation*. Springer.
5. Ghosh, J. K., Delampady, M. and Samanta, T. *An Introduction to Bayesian Analysis: Theory and Methods*. Springer.
6. Lee, P. M. *Bayesian Statistics: An Introduction*. Wiley.
7. Hoff, P. D. *A First Course in Bayesian Statistical Methods*. Springer.

5-ST-MJ-805 Nonparametric Methods (Marks – 60, Credit – 4)

Empirical distribution function and quantile function, Kolmogorov-Smirnov goodness of fit test. 6L

One- and two-sample U-statistics, statement of the asymptotic normality of U-statistics, linear rank statistics, statement of the asymptotic normality under the hypothesis. 10L

One-sample location and scale problems, paired sample problems,Sign test, Wilcoxon signed rank test, two-sample homogeneity problem, Location and scale alternatives in the two-sample problem, Wilcoxon rank-sum test,Mann-Whitney tests,median test, Mood's test and the normal and inverse normal scores tests. 16L

Runs test for randomness,Wald-Wolfowitz runs test. 4L

One-way and two-way classification, Kruskal-Wallis and Friedman's tests. 4L

Measures of rank correlation: Spearman's rho and Kendall's tau. 4L

Confidence intervals related to the Median and the Mann-Whitney tests in one and two-sample problems. 4L

References:

1. Gibbons, J.D.& Chakraborti, S.: Nonparametric Statistical Inference.
2. Goon, A.M., Gupta, M.K., Dasgupta, B.: An Outline of Statistical Theory, Vol.2.
3. Hollander, M., Wolfe, D.A.: Nonparametric Statistical Methods.
4. Wasserman, L.: All of Nonparametric Statistics.

5-ST-MJ-806 Design of Experiments (Marks: 60, Credit: 4)

Concepts of connectedness, orthogonality and variance balance; intrablock analysis of incomplete block designs; Balanced Incomplete Block Designs (BIBD)—parameters, existence conditions, properties and analysis; recovery of interblock information and its applications in BIBD; justification of missing plot techniques. 14 L

Construction of Balanced Incomplete Block Designs (BIBD); Partially Balanced Incomplete Block Designs (PBIBD)—association schemes, properties and analysis; lattice designs; dual and linked block designs; resolvable BIBDs; Youden square designs; introduction to finite (Galois) fields and their applications in the construction of mutually orthogonal Latin squares, BIBDs and orthogonal arrays (prime power case); construction of mutually orthogonal Latin squares (prime power case). 12 L

Symmetrical factorial experiments; confounding and balance in symmetric factorial designs (prime power case); construction and analysis of confounded factorial designs; fractional factorial designs; orthogonal arrays and balanced arrays; examples of and designs (without proof). 12 L

Introduction to response surface methodology; first-order response surface designs; orthogonality, rotatability and blocking; Central Composite Designs (CCD); Box–Behnken Designs; applications of response surface methodology. 10 L

References

1. Chakrabarti, M. C. *Mathematics of Design and Analysis of Experiments*.
2. Kempthorne, O. *The Design and Analysis of Experiments*. John Wiley & Sons.
3. Cochran, W. G. and Cox, G. M. *Experimental Designs*. John Wiley & Sons.
4. Federer, W. T. *Experimental Design: Theory and Application*.
5. Das, M. N. and Giri, N. C. *Design and Analysis of Experiments*. Wiley Eastern Ltd.
6. Dey, A. *Theory of Block Designs*. Wiley Eastern Ltd.
7. John, P. W. M. *Statistical Design and Analysis of Experiments*. Macmillan.
8. Nigam, A. K., Puri, P. D. and Gupta, V. K. *Handbook of Analysis of Experimental Designs*.
9. Montgomery, D. C. *Design and Analysis of Experiments*. John Wiley & Sons.
10. Myers, R. H., Montgomery, D. C. and Anderson-Cook, C. M. *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*. Wiley.
11. Box, G. E. P. and Draper, N. R. *Response Surfaces, Mixtures, and Ridge Analyses*. Wiley.
12. Khuri, A. I. and Cornell, J. A. *Response Surfaces: Designs and Analyses*. CRC Press.

SEMESTER 9

5-ST-SEC-901: Research Methodology & IKS (Marks: 60, Credit: 4)

Foundations of Research Methodology: Meaning, objectives and motivation of research; scientific method;deductive and inductive reasoning; concepts of theory, empiricism, hypothesis, variables and research questions; identification and formulation of research problems; research design; qualitative and quantitative research; exploratory, descriptive and experimental research; sampling and questionnaire design; preparation of research proposals. 12L

Scientific Writing, Publication Ethics and Research Evaluation : Structure of a scientific paper; abstract, introduction, methodology, results, discussion, references and acknowledgements; preparation of review articles, book chapters, posters and conference presentations; plagiarism, fabrication, falsification and publication misconduct; authorship and conflict of interest; COPE guidelines; similarity checking software;reference management software (Mendeley, Zotero, EndNote); indexing databases (Scopus, Web of Science, Google Scholar); citation metrics (Impact Factor, h-index, CiteScore, SNIP, SJR); predatory journals and conferences; UGC-CARE and responsible research assessment. 14L

Indian Knowledge System (IKS) in Statistics and Mathematical Sciences: Introduction to the Indian Knowledge System; evolution of mathematical and statistical ideas in ancient and medieval India; contributions of Pingala, Aryabhata, Brahmagupta, Bhaskara II, Madhava of the Kerala School and Hemachandra; combinatorics,binomial coefficients and the Meru Prastāra (Pascal triangle); probability ideas in ancient Indian games and literature; statistics in the Arthashastra and ancient administrative systems; history of census and official statistics in India; contributions of P. C. Mahalanobis, R. C. Bose, C. R. Rao, S. N. Roy, D. B. Lahiri, and the Indian Statistical Institute; role of statistics in national planning and development. 14L

Statistical Literature Review: Literature survey using scientific databases; critical reading of statistical journal articles; preparation of literature reviews; reviewing classical and

contemporary statistical papers, preparation of technical reports and project reports; research communication. Introduction to LaTeX; installation and document structure; document classes and packages; formatting text and mathematical expressions; tables and figures; cross-referencing, citations and bibliography using BibTeX; preparation of reports, research papers and presentations using Beamer; preparation of dissertations and theses; introduction to Overleaf. 10L

Reference

1. C. R. Kothari – Research Methodology: Methods and Techniques
2. Robert A. Day & Barbara Gastel – How to Write and Publish a Scientific Paper
3. Michael Alley – The Craft of Scientific Writing
4. Wayne C. Booth et al. – The Craft of Research
5. Nicholas Walliman – Research Methods: The Basics
6. Pandey & Pandey – Research Methodology: Tools and Techniques
7. Sugimoto & Larivière – Measuring Research
8. Springer Handbook of Science and Technology Indicators
9. Kapil Kapoor & Avadesh Kumar Singh – Indian Knowledge Systems
10. B. Mahadevan – Introduction to Indian Knowledge System
11. C. R. Rao — Statistics and Truth
12. J. K. Ghosh — Statistical Thought: A Perspective and History (selected chapters)
13. C. R. Rao. — Statistics: Reflections and Memories
14. Lamport,L. *LaTeX: A Document Preparation System: User's Guide and Reference Manual*. Addison-Wesley.
15. Helmut Kopka and Patrick W. Daly, *A Guide to LaTeX,* Addison-Wesley.

5-ST-MJ-902 Advanced Regression Analysis (Marks – 60, Credit – 4)

Classical Linear Regression Model: Polynomial regression models, Multicollinearity, Regularization techniques: Ridge, Lasso, Elastic net. 6L

Generalized Linear Models (GLM): Concept of GLM, link function, estimation of parameters. Models for binary data: logistic, probit. Models for multinomial data: multinomial logit. Models for ordinal data: cumulative logit. Models for count data: Poisson regression, negative binomial regression. 18L

Linear mixed model: Multilevel data, linear mixed model, estimation of parameters, EM algorithm. 8L

Spatial Regression: Spatial Data, spatial autocorrelation, LM diagnostics, spatial lag model, spatial error model, Geographically Weighted Regression (GWR). 12L

Quantile Regression: Basic concept, quantile regression model, estimation of parameters. 4L

Reference:

1. McGullagh, P and Nelder, J.A. (1989), Generalized Linear Models, London: Chapman and Hall.
2. Agresti, A. (2015), Foundations of Linear and Generalized Linear Models, Wiley Series in Probability and Statistics.
3. Agresti, A. (2012), Categorical Data Analysis, 3rd edition, Wiley Series in Probability and Statistics.
4. Dobson & Barnett (2008), An Introduction to Generalized Linear Models, Taylor & Francis.
5. Hastie, T., Tibshirani, R., Friedman, J.H. and Friedman, J.H. (2009): The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Vol 2.
6. Anselin, L.: Spatial Econometrics: Methods and Models.
7. Haining, R (2003): Spatial Data Analysis: Theory and Practice.
8. Seymour, L. (2005). Spatial Data Analysis: theory and practice.
9. Koenker, R: Quantile Regression.

5-ST-MJ-903 Reliability and Life-testing (Marks – 60, Credit – 4)

System Reliability: Reliability concepts and measures; components and systems, coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on systems reliability and reliability importance of components. 8L

Basic Quantities and Models: Life distributions, survival functions, hazard rate, residual life time, mean residual life function, one-one correspondence of these functions, common life distributions, exponential, Weibull, gamma, Makeham, Pareto, Rayleigh, lognormal etc. 6L

Notion of Aging: IFR, IFRA, DMRL, NBU, NBUE, HNBUE classes and their duals for continuous and discrete setups. Exponential distribution and its non-ageing property. 6L

Life Testing: Censoring and Truncation. Type-I, Type-II and Random Censoring. Maximum likelihood estimation under random censoring, method of scoring. Tests based on MLE, Wald type test, LR test and Score test. Hybrid censoring, Progressive Type-II censoring, Progressive Type-I interval censoring and related inference. 10L

Multivariate Reliability: Vector concept of hazard rate, multivariate lack of memory property, properties of multivariate exponential distribution due to Marshall and Olkin. Other multivariate exponential and Weibull distributions. Inference under random censoring for bivariate cases. Multivariate reliability analysis using Copula, Sklar's Theorem, Series and Parallel systems for dependent components. 10L

Reliability Engineering: Univariate shock models, repairable systems, redundancy optimization, Stress-Strength Reliability and Accelerated Life tests. 8L

Reference:

1. Barlow, R. E., and Proschan, F.: Statistical Theory of Reliability and Life Testing, Holt, Rinehart and Winston.
2. Barlow, R. E., and Proschan, F.: Mathematical Theory of Reliability, SIAM.
3. Lawless, J. F.: Statistical Models and Methods of Lifetime Data, Wiley.
4. Mukherjee, S. P. and Nanda, A. K.: Probability Models in Reliability Analysis, Springer.
5. Finkelstein, M. and Cha, J. H.: Stochastic Modeling for Reliability, Springer.
6. Rausand, M. and Hoyland, H.: System Reliability Theory Models, Statistical Methods and Applications, Wiley.
7. Kapur, K. C. and Lamberson, L. R.: Reliability in Engineering Design, Wiley.
8. Bain, Lee, J. and Max Engelhardt: Statistical Analysis of Reliability and Life-Testing Models: Theory and Methods, Marcel Decker.
9. Rigdon, S. E. and Basu, A. P.: Statistical Methods for the Reliability of Repairable Systems, Wiley.

5-ST-MJ-904 Operations Research (Marks – 60, Credit – 4)

Definition and scope of OR. Phases in OR. 2L

Review of linear programming problem, methods of solution, duality of LPP, transportation and assignment problems with proof of relevant results, travelling salesman problem. 12L

Inventory control- Classical inventory model, EOQ model with price breaks, Probabilistic EOQ models. 10L

Queueing systems- Generalized Poisson queueing model, specialised Poisson queues such as (M/M/1) : (GD/∞/∞), (M/M/1) : (FIFO/∞/∞), (M/M/c) : (GD/∞/∞) etc. 8L

Simulation- Monte-Carlo method, generation of random observations from a few standard distributions. 6L

Information theory- Communication processes, entropy as a measure of information, marginal and joint entropy, mutual information with proofs of relevant results. Axiom of entropy. Encoding, Shannon-Fano procedure. Differential entropy and Kullback-Leibler divergence, relationship with Fisher Information. Maximum entropy distributions under different moment constraints. 10L

Reference:

1. Taha, H.A.: Operations Research: An Introduction, 6th Ed. 1997 Prentice–Hall of India.
2. Hadley, G. (1962): Linear Programming, Addison-Wesley.
3. Gass, S. (1958): Linear Programming: Methods and Applications, McGraw-Hill.
4. Goel and Mittal: Operations Research, Sultan Chand.
5. Kanti Swarup, P.K. Gupata & M.M. Singh (1985): Operations Research, Sultan Chand.
6. Cover, T. M., & Thomas, J. A. (2006). Elements of Information Theory. John Wiley & Sons, Hoboken, New Jersey.

5-ST-SEC-905 Python Programming (Marks – 60, Credit – 4)

Introduction 6L

Structure of a Python Program, Elements of 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).

Creating Python Programs 6L

Input and Output Statements, Control statements (Branching, Looping, Conditional Statement, Exit function, Difference between break, continue and pass.), Defining Functions, default arguments, Errors and Exceptions.

Iteration and Recursion 5L

Conditional execution, Alternative execution, Nested conditionals, The return statement, Recursion, Stack diagrams for recursive functions, Multiple assignment, The while statement, Tables, Two-dimensional tables.

Strings and Lists 6L

String as a compound data type, Length, Traversal and the for loop, String slices, String comparison, A find function, Looping and counting, List values, Accessing elements, List length, List membership, Lists and for loops, List operations, List deletion. Cloning lists, Nested lists.

Object Oriented Programming 6L

Introduction to Classes, Objects and Methods, Standard Libraries.

Data Structures 4L

Arrays, list, set, stacks and queues.

Searching and Sorting 5L

Linear and Binary Search, Bubble, Selection and Insertion sorting.

Python for Data science 6L

Introduction to NumPy, SciPy, Matplotlib and Pandas. Scikit-learn.

Idea of Parallel Computing and Efficient Programming. 4L

References :

1. T. Budd, Exploring Python, TMH, 1st Ed, 2011
2. How to think like a computer scientist : learning with Python / Allen Downey,
3. Jeffrey Elkner, Chris Meyers. 1st Edition – Freely available online.2012

Semester 10

5-ST-DSE-1001 Multivariate Techniques (Marks-60, Credit-4)

Multivariate normal distribution and its properties, MLEs of parameters.Distribution of sample mean vector, Wishart matrix-its distribution (with out derivation) and properties, Null distribution of Hotelling T^2 statistic and its application (including simultaneous confidence interval), Mahonalobis D^2 statistic.

Organization and representation of multivariate data.

Dimension Reduction Techniques :

a) Principal Component Analysis Concept, Computation, Large sample Inferences.

b) Canonical Correlation Analysis: Concept, Computation, Large sample, Inferences.

c) Exploratory Factor Analysis: Concept, Factor model, estimation of factor landings, factor rotation, estimating factor scores, Model fit.

Multivariate Analysis of Variance: One-way and two-way classified data with one observation per cell.

Discriminant Analysis: Likelihood ratio, Bayes and minimax procedures, Discrimination between two multivariate normal populations with common dispersion, Sample discriminate function, estimation, Fisher's method for discriminating among several populations.

Multidimensional Scaling: Classical Metric Scaling, Non-metric scaling.

References:

1. Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis.
2. Kshirsagar, A.M. Multivariate Analysis.
3. Morrison, D.F. Multivariate. Statistical Methods.
4. Seber, G.A.F. Multivariate Observations.
5. Mardia, Kent and Bibby.

5-ST-MJ-1002 Artificial Intelligence and Machine Learning (Marks – 60, Credit – 4)

Introduction to Machine Learning, Supervised and Unsupervised learning, Classification of problems – Regression and Classification. 6L

Linear Regression: Linear least squares regression, subset selection, shrinkage, Regularization: Ridge, Lasso and Elastic-net regression. 6L

Classification: Linear Discriminant Analysis (LDA), logistic regression, regularized logistic regression. 6L

Decision Tree, Random Forest. 6L

Neural Networks: Neural networks, Fitting neural networks, hidden units and layers. 6L

Support Vector Machines: Support vector classifier, SVM for classification, generalizing linear discriminant Analysis. 6L

Unsupervised learning: Introduction, k-Means Algorithm, Optimization objective. 6L

Gen AI and Large Language Model (LLM). 6L

Reference:

1. Hastie, T., Tibshirani, R., Friedman, J.H. and Friedman, J.H. (2009): The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Vol 2.
2. Kalita, J.K., Bhattacharya, D.K., Roy, S.: Fundamentals of Data Science: Theory and Practice.
3. James, G., Witten, D., Hastie, T. and Tibshirani, R.: *An Introduction to Statistical Learning: With Applications in R*. Springer.
4. Bishop, C. M.: *Pattern Recognition and Machine Learning*. Springer.

5. Alpaydin, E.: *Introduction to Machine Learning*. MIT Press.
6. Goodfellow, I., Bengio, Y. and Courville, A.: *Deep Learning*. MIT Press.
7. Russell, S. and Norvig, P.: *Artificial Intelligence: A Modern Approach*. Pearson.
8. Jurafsky, D. and Martin, J. H.: *Speech and Language Processing*. Pearson

Elective Papers: 5ST-DSE-1003

5ST-DSE-1003 Survival Analysis and Clinical Trials

Fundamentals of Survival Analysis: Introduction to survival analysis; survival, hazard and cumulative hazard functions; survival distributions and their applications—Exponential, Gamma, Weibull, Rayleigh and Lognormal distributions; bathtub-shaped hazard function; censoring and truncation; Type I, Type II, progressive and random censoring with biological examples; estimation of mean survival time under Type I and Type II censoring; non-parametric estimation of survival functions using Actuarial and Kaplan–Meier methods; comparison of survival curves using the Log-rank test. **16L**

Competing Risks and Regression Models: Competing risk theory; indices for measuring probabilities of failure under competing risks and their interrelations; estimation using maximum likelihood and modified minimum chi-square methods; independent and dependent competing risks; bivariate normal dependent risk model; introduction to Cox proportional hazards regression and hazard ratio. **10L**

Fundamentals of Clinical Trials: Introduction to clinical trials; phases of clinical trials (Phase I–IV); protocol development; control groups; placebo and active controls; ethical principles in clinical trials; informed consent; Good Clinical Practice (GCP); blinding and masking; sources of bias; sample size determination (basic concepts); monitoring and reporting of clinical trials. **12L**

Randomization Procedures in Clinical Trials: Randomized clinical trials; balancing treatment assignments; complete and restricted randomization; random allocation rule; truncated binomial design; Efron’s biased coin design; Wei’s urn design; covariate-adaptive randomization; response-adaptive randomization; ethical issues in adaptive randomization; applications in modern clinical trials. **10L**

References

1. Indrayan, A. Medical Biostatistics. 2nd Edition, Chapman & Hall/CRC.

2. Biswas, S. Applied Stochastic Processes: A Biostatistical and Population Oriented Approach. New Central Book Agency.
3. Lee, E. T. and Wang, J. W. Statistical Methods for Survival Data Analysis. 3rd Edition, John Wiley & Sons.
4. Chiang, C. L. Introduction to Stochastic Processes in Biostatistics. John Wiley & Sons.
5. Collett, D. Modelling Survival Data in Medical Research. Chapman & Hall/CRC.
6. Klein, J. P. and Moeschberger, M. L. Survival Analysis: Techniques for Censored and Truncated Data. Springer.
7. Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M. and Granger, C. B. Fundamentals of Clinical Trials. Springer.
8. Rosenberger, W. F. and Lachin, J. M. Randomization in Clinical Trials: Theory and Practice. John Wiley & Sons.
9. Chow, S. C. and Liu, J. P. Design and Analysis of Clinical Trials: Concepts and Methodologies. John Wiley & Sons.
10. Chen, D.-G. (Din) and Peace, K. E. Clinical Trial Data Analysis Using R. Chapman & Hall/CRC.

OR

5ST-DSE-1003 Actuarial Statistics

Probability Models and Life Tables : Introduction to actuarial science; utility theory and insurance; probability models for individual and aggregate claims; survival function, curtate future lifetime and force of mortality; life tables and their relationship with survival functions; complete and abridged life tables; select and ultimate life tables; assumptions for fractional ages; analytical laws of mortality including Gompertz and Makeham laws. **12 L**

Multiple Life Models and Risk Theory : Multiple life functions; joint life and last survivor status; multiple decrement models; deterministic and random survivorship groups; associated single decrement tables; central rates of multiple decrement; distribution of aggregate claims; compound Poisson distribution and its applications; introduction to stop-loss insurance and claim amount distributions. **12 L**

Life Insurance and Life Annuities: Principles of compound interest; nominal and effective rates of interest and discount; force of interest; accumulation and discount factors; life insurance contracts—term insurance, whole life insurance, endowment insurance, deferred insurance and varying benefit insurance; life annuities—continuous and discrete annuities, annuities-due and annuities-immediate, monthly payment annuities; commutation functions and recursive relationships. **14 L**

Premiums and Actuarial Reserves: Net premiums; continuous and discrete premium calculation; premium payment schemes; net premium reserves; continuous and discrete reserves; reserves at fractional durations; recursive reserve calculations; practical considerations in premium calculation including expense loadings; applications in life insurance and pension schemes. **10 L**

References:

1. Bowers, N. L., Gerber, H. U., Hickman, J. C., Jones, D. A. and Nesbitt, C. J. Actuarial Mathematics. Society of Actuaries, 2nd Edition.
2. Dickson, D. C. M., Hardy, M. R. and Waters, H. R. Actuarial Mathematics for Life Contingent Risks. Cambridge University Press.
3. Atkinson, M. E. and Dickson, D. C. M. An Introduction to Actuarial Studies. Elgar Publishing.
4. Neill, A. Life Contingencies. Heinemann.
5. Spurgeon, E. T. Life Contingencies. Cambridge University Press.
6. Gerber, H. U. Life Insurance Mathematics. Springer.
7. Rolski, T., Schmidli, H., Schmidt, V. and Teugels, J. Stochastic Processes for Insurance and Finance. John Wiley & Sons.
8. Bedford, T. and Cooke, R. Probabilistic Risk Analysis: Foundations and Methods. Cambridge University Press.
9. Philip, M., Booth, P., Chadburn, R., Cooper, D. and Haberman, S. Modern Actuarial Theory and Practice. Chapman & Hall/CRC.
10. Promislow, S. D. Fundamentals of Actuarial Mathematics. John Wiley & Sons.

OR

5ST-DSE-1003 Public Health Statistics and Epidemiology

Health Statistics and Disease Measurement: Introduction to public health and epidemiology; measures of disease frequency: incidence, prevalence, attack rate and secondary attack rate; measures of mortality and morbidity; case fatality rate, standardized mortality ratio; disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs); health indicators; sources of health data; national health surveys and health information systems. **12 L**

Epidemiological Study Designs: Observational and experimental studies; cross-sectional, ecological, case-control and cohort studies; design, advantages and limitations; selection of study subjects; matching; confounding; bias and its control; randomized controlled

trials; crossover trials; sample size considerations; recruitment strategies; screening programmes; sensitivity, specificity, predictive values and ROC curves. **14 L**

Spatial and Infectious Disease Epidemiology: Geographical representation and disease mapping; spatial interpolation and smoothing methods; estimation and inference in spatial epidemiology; spatial proximity indices; disease clustering; spatial regression; introduction to infectious disease modelling; surveillance systems and outbreak investigation; applications in public health. **12 L**

Modern Statistical Methods in Epidemiology: Measures of association: relative risk, odds ratio and attributable risk; survival analysis in epidemiology; applications of Kaplan–Meier estimator and Cox proportional hazards model; introduction to logistic regression; disease risk prediction models; introduction to statistical genomics, genome-wide association studies (GWAS), biomarkers and precision medicine; case studies in epidemiological and public health research. **10 L**

References

1. Gordis, L. Epidemiology. Elsevier.
2. Rothman, K. J., Greenland, S. and Lash, T. L. Modern Epidemiology. Lippincott Williams & Wilkins.
3. Friis, R. H. and Sellers, T. A. Epidemiology for Public Health Practice. Jones & Bartlett Learning.
4. Bonita, R., Beaglehole, R. and Kjellström, T. Basic Epidemiology. World Health Organization.
5. Kleinbaum, D. G., Kupper, L. L., Nizam, A. and Rosenberg, E. S. Applied Regression Analysis and Other Multivariable Methods. Cengage.
6. Lawson, A. B. Statistical Methods in Spatial Epidemiology. Wiley.
7. Elliott, P., Wakefield, J., Best, N. and Briggs, D. Spatial Epidemiology: Methods and Applications. Oxford University Press.
8. Indrayan, A. Medical Biostatistics. Chapman & Hall/CRC.

OR

5ST-DSE-1003 Advanced Time Series Analysis

Advanced Univariate Time Series : Time series as a discrete-parameter stochastic process; review of weak stationarity and properties of autocovariance and autocorrelation functions; estimation of mean, autocovariance and autocorrelation functions under

large-sample theory; exploratory time series analysis; tests for trend and seasonality; advanced seasonal modelling; Seasonal ARIMA (SARIMA) models; intervention analysis and dynamic regression models; deterministic and stochastic trends; structural breaks and change-point models. **12 L**

State-Space Models and Advanced Forecasting: State-space representation of time series models; observation and state equations; local-level and local-trend models; structural time series models; Kalman filtering and smoothing; forecasting using state-space models; forecast uncertainty and prediction intervals; exponential smoothing in the state-space framework; forecast evaluation and comparison; rolling-origin evaluation and time-series cross-validation. **12 L**

Multivariate Time Series Analysis: Introduction to multivariate time series; vector autoregressive (VAR) models; estimation and interpretation of VAR models; vector moving average representation; Granger causality; impulse response functions; forecast error variance decomposition; spurious regression; cointegration; error correction models (ECM); vector error correction models (VECM); Johansen's approach to cointegration.

12 L

Spectral, Volatility and Nonlinear Time Series: Spectral analysis; periodogram and spectral density; long-memory processes and fractional differencing; time-varying volatility; ARCH and GARCH models; advanced volatility models including EGARCH and GJR-GARCH; volatility forecasting; nonlinear time series models including threshold autoregressive (TAR) and smooth transition autoregressive (STAR) models; regime-switching and Markov-switching models; applications to economic, financial and environmental time series. **12 L**

References

1. Shumway, R. H. and Stoffer, D. S. Time Series Analysis and Its Applications: With R Examples. Springer.
2. Brockwell, P. J. and Davis, R. A. Introduction to Time Series and Forecasting. Springer.
3. Hamilton, J. D. Time Series Analysis. Princeton University Press.
4. Box, G. E. P., Jenkins, G. M., Reinsel, G. C. and Ljung, G. M. Time Series Analysis: Forecasting and Control. John Wiley & Sons.
5. Lütkepohl, H. New Introduction to Multiple Time Series Analysis. Springer.
6. Tsay, R. S. Analysis of Financial Time Series. John Wiley & Sons.
7. Priestley, M. B. Spectral Analysis and Time Series. Academic Press.
8. Durbin, J. and Koopman, S. J. Time Series Analysis by State Space

Elective Papers: 5ST-DSE-1004

5ST-DSE-1004 Advanced Inference

Resampling Techniques: The Jackknife, bias correction, Jackknife estimate of variance, consistency of jackknife (Rupert Miller) and related results. **6L**

The Bootstrap, consistency of Bootstrap (Kesar Singh), discussions on Bootstrap consistency for sample quantile, smooth function of sample mean and in variance estimation. Accuracy of Bootstrap, Bootstrap confidence intervals. **14L**

Deleted Jackknife and m-out-of-n Bootstrap. **4L**

Goodness-of-fit tests: Uniformity, Normality and Exponentiality tests, general purpose goodness-of-fit tests. Goodness-of-fit tests for distributions under censored data. **12L**

Density Estimation: Histogram estimator, Rosenblatt Estimator, Kernel Density Estimator and sample spacings-based estimators. **12L**

References:

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OR

5ST-DSE-1004 Bayesian Inference

Historical background and motivation behind Bayesian Inference. 2L

The Bayesian Model Assumptions, Basic examples and advantages of Bayesian Modeling. 2L

Choice of Priors: Objective and subjective priors. Conjugate Priors, natural conjugate family: advantages and existence. PKD theorem (without proof) and related results.

Non-information priors: Laplace Prior and maximum entropy, Jefferey's prior and related examples. Jefferey's prior as a minimizer of KL Divergence. 16L

Bayesian estimation: Asymptotic of the posterior, Bernstein-Von-Mises Theorem and related results, Doob's theorem. 8L

Bayesian Hypothesis Testing 4L

Bayesian Model selection 4L

Bayesian Computation: MCMC, Metropolis Hasting, Gibbs. 6L

Hierarchical Bayes concepts 2L

Non-parametric bayes: Dirichlet process prior. 4L

References:

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5. Ghosal, S and van der Vaart, A. (2017): Fundamentals of Nonparametric Bayesian Inference, Cambridge University Press.

OR

5ST-DSE-1004 Industrial Statistics

General Theory and review of control charts for variables and attributes. OC and ARL of control charts; moving average and exponentially weighted moving average charts; CUSUM charts using V-masks and decision intervals. 10L

Group control charts for Multiple-Stream Process and DNOM chart for Short Run Process. Attribute charts for Short Run Process. 4L

Autocorrelated Quality Characteristics: Detection and measure of autocorrelation. Dealing with autocorrelation, Time series model-based approach for monitoring autocorrelated processes. Model-Free approach. 4L

Multivariate Control Chart: Multivariate quality control problem, Chi-square control chart, Estimation of mean vector and dispersion matrix for multivariate normal distribution and Hotelling control chart. Multivariate control chart for individual observations and process variability. 6L

Economic design of control chart: Duncan's Single Assignable Cause Model for Economic Design of Chart. 4L

Engineering Process Control: Determination of feedback adjustment (Integral control) scheme, manual implementation adjustment chart, combining SPC and EPC. 4L

Continuous Sampling Plans: Dodge type and Wald-Wolfowitz type and their properties. Mil. Std. Plans. 5L

Process Capability Indices: PCI for non-normal distributions. 5L

Online Quality Control (Taguchi Methods): Loss function and quality level, derivation of the loss function, loss function and inspection. Online quality control for attributes. 6L

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OR

5ST-DSE-1004 Advanced Operations Research

Sensitivity analysis in linear programming problems. 4L

Nonlinear programming: graphical method, classical optimization technique, Kuhn-Tucker theorem, Wolfe's algorithm in quadratic programming. 6L

Dynamic programming, Bellman's principle of optimality, general formulation, applications. 6L

Inventory problems, deterministic model, multiple item static model with storage limitation, continuous review model, ABC analysis. 6L

Stochastic programming, chance-constrained programming under normality. 5L

Integer programming, branch and bound and cutting plane method. 5L

Replacement problems, replacement of items that depreciate, block and age replacement policies, staffing problem. 5L

Goal programming. 5L

Sequencing models, Sequencing n jobs on two machines. 2L

Introduction to networks, determination of floats and critical paths, CPM & PERT. 4L

References:

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