UNIVERSITY OF CALCUTTA

Notification No. CSR/79/2025

It is notified for information of all concerned that in terms of the provisions of Section 54 of the Calcutta University Act, 1979, (as amended), and, in the exercise of her powers under 9(6) of the said Act, the Vice-Chancellor has, by an order dated 15.10.2025 approved the new revised Course structure and Syllabus for (semester-1 to 6) of Statistics (4-year Honours & Honours with Research/ 3-year MDC) including Question Patterns, under CCF, 2022.

The above shall take effect from the Odd semester examinations, 2025 and onwards.

29/10/2025

Prof.(Dr.) Debasis Das

Registrar

SENATE HOUSE

Kolkata-700073

29.10.2025

UNIVERSITY OF CALCUTTA

Syllabus

for

Four-year / Three-year B.Sc. Courses of Studies

in

STATISTICS

(Under Curriculum & Credit Framework, 2022)

[Semesters I, II, III, IV, V and VI]

UNIVERSITY OF CALCUTTA

Syllabus

for

Four-year B.Sc. (Honours & Honours with Research) Courses of Studies

in

STATISTICS

(Under Curriculum & Credit Framework, 2022)

[Semesters I, II, III, IV, V and VI]

With effect from the Academic Session

2023-24

Structure of Statistics Major Courses

Semester	Course / Paper Code	Course Name
I	STAT-H-CC1-1-Th / P	Descriptive Statistics I & Probability I
	STAT-H-SEC1-1-Th / P	Numerical Computations with C
II	STAT-H-CC2-2-Th / P	Descriptive Statistics II & Probability II
	STAT-H-SEC2-2-Th / TU	Artificial Intelligence for Everyone
III	STAT-H-CC3-3-Th / TU	Real Analysis I
	STAT-H-CC4-3-Th / P	Statistical Inference I
	STAT-H-SEC3-3-P	Introduction to R
IV	STAT-H-CC5-4-Th / P	Linear Algebra
	STAT-H-CC6-4-Th / P	Probability III
	STAT-H-CC7-4-Th / P	Sampling Distributions and Statistical Inference II
	STAT-H-CC8-4-Th / P	Design of Experiments I and Sample Survey I
V	STAT-H-CC9-5-Th / P	Multivariate Analysis I
	STAT-H-CC10-5-Th / P	Statistical Inference III
	STAT-H-CC11-5-Th / P	Linear Models
	STAT-H-CC12-5-Th / P	Demography, Index Numbers and Psychometry
VI	STAT-H-CC13-6-Th / P	Applied Multivariate Analysis
	STAT-H-CC14-6-Th / P	Regression Analysis
	STAT-H-CC15-6-Th / P	Time Series Analysis

Structure of Statistics Minor Courses

Semester	Course / Paper Code	Course Name
I	STAT-H-MC1-1-Th / P	Descriptive Statistics I & Probability I
II	STAT-H-MC2-2-Th / P	Descriptive Statistics II & Probability II
III	STAT-H-MC1-3-Th / P	Descriptive Statistics I & Probability I
IV	STAT-H-MC2-4-Th / P	Descriptive Statistics II & Probability II
V	STAT-H-MC3-5-Th / P	Statistical Inference I
	STAT-H-MC4-5-Th / P	Design of Experiments I and Sample Survey I
VI	STAT-H-MC3-6-Th / P	Statistical Inference I
	STAT-H-MC4-6-Th / P	Design of Experiments I and Sample Survey I

Structure of Statistics Interdisciplinary Course

Semester	Course / Paper Code	Course Name
I	STAT-H-IDC1-1-Th / P	Statistics for Practitioners
II	STAT-H-IDC2-2-Th / P	
III	STAT-H-IDC3-3-Th / P	

Question Patterns

SEMESTER - I

STATISTICS MAJOR

STAT-H-CC1-1-Th **3 Credits**

(Descriptive Statistics I & Probability I) **THEORY**

Statistics: Definition and scope. Concepts of statistical population and sample.

Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous.

Scales of measurement: nominal, ordinal, interval and ratio.

Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays. (10)

Measures of Central Tendency: Mean, Median, Mode.

Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation, Ginis Coefficient, Lorenz Curve. Moments, skewness and kurtosis. Quantiles and measures based on them. Box Plot. Outliers. (15)

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability: classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (20)

STAT-H-CC1-1-P **1 Credit**

(Descriptive Statistics I & Probability I) **PRACTICAL**

List of Suggested Practical

- Diagrammatic representation of data.
- Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations, stem and leaf plot.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation.
- Problems based on moments, skewness and kurtosis.
- Problems related to quantiles and measures based on them, construction of box plot.
- Application problems based on Classical Definition of Probability.
- Application problems based on Bayes' Theorem.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STAT-H-SEC1-1-Th **2 Credits**

(Numerical Computations with C) **THEORY**

Numerical Analysis:

Approximation of numbers and functions. Absolute and Relative errors.

Interpolation: Polynomial approximation, Weierstrass Theorem (Statement). Difference Table, Newton's Forward and Backward interpolation formulae and Lagrange's general interpolation formula, Error terms.

Numerical Differentiation and its applications.

Numerical Integration: Trapezoidal and Simpson's 1/3rd rules.

Numerical solution of equations: method of fixed-point iteration and Newton-Raphson method in one unknown, conditions of convergence (statement only). (15)

C-programming:

Components, basic structure programming, character set, C/C++ tokens, Keywords and Identifiers and execution of a C/C++ program.

Data types: Basic data types, enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, symbolic constants, overflow and underflow of data.

Operators and expressions: library functions.

Managing input and output operations: reading and printing formatted and unformatted data.

Decision making and branching: if...else, nesting of if...else, else if ladder, switch.

Looping in C/C++: for, nested for, while, do...while, and jumps in and out of loops.

Arrays: Declaration and initialization of one-dim and two-dim arrays. User-defined functions.

(15)

STAT-H-SEC1-1-P **2 Credits**

(Numerical Computations with C) **PRACTICAL**

List of Suggested Practical

- Finding values of a function $y = f(x)$ for given values of x.
- Roots of a quadratic equation (with imaginary roots also).
- Sorting of an array and hence finding median.
- Mean, median and mode of a grouped frequency Data.
- Variance and coefficient of variation of a grouped frequency data.
- Preparing a frequency table.
- Numerical methods: Interpolation by Lagrange's formula, Solving one-variable equations using Newton-Raphson and iteration methods.
- Trapezoidal and Simpson's 1/3rd rule for numerical integration with convergence.
- Storing the C output in a file.

Reference Books:

- Kernighan, B.W. and Ritchie, D.: C Programming Language, 3rd Edition, Prentice Hall.
- Balagurusamy, E.: Programming in ANSI C, 6th Edition, Tata McGraw Hill.
- Gottfried, B.S.: Schaums Outlines: Programming with C, 2nd Edition, Tata McGraw Hill.
- Jain, M. K., Iyengar, S. R. K. and Jain, R. K.: Numerical methods for scientific and engineering computation, New age International Publisher, India.
- Mukherjee, Kr. Kalyan: Numerical Analysis, New Central Book Agency.
- Sastry, S.S.: Introductory Methods of Numerical Analysis, 3rd edition, Prentice Hall of India Pvt. Ltd., New Delhi.
- Scarborough, J.B.: Numerical Mathematical Analysis, Oxford and IBH Publishing.

STATISTICS MINOR

STAT-H-MC1-1-Th **3 Credits**

(Descriptive Statistics I & Probability I) **THEORY**

Statistics: Definition and scope. Concepts of statistical population and sample.
Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous.
Scales of measurement: nominal, ordinal, interval and ratio.
Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays. (10)

Measures of Central Tendency: Mean, Median, Mode.
Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation, Ginis Coefficient, Lorenz Curve. Moments, skewness and kurtosis. Quantiles and measures based on them. Box Plot. Outliers. (15)

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability: classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (20)

STAT-H-MC1-1-P **1 Credit**

(Descriptive Statistics I & Probability I) **PRACTICAL**

List of Suggested Practical

- Diagrammatic representation of data.
- Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations, stem and leaf plot.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation.
- Problems based on moments, skewness and kurtosis.
- Problems related to quantiles and measures based on them, construction of box plot.
- Application problems based on Classical Definition of Probability.
- Application problems based on Bayes' Theorem.

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- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STATISTICS INTERDISCIPLINARY

STAT-H-IDC1-1-Th **2 Credits**

(Statistics for Practitioners) **THEORY**

Understanding univariate data: Variable, notion of population and sample, different types of data, methods of collecting primary and secondary data, presentation of data, summary measures on data with central tendency (arithmetic mean, median, mode), dispersion (range, quartile deviation, standard deviation, coefficient of variation), ideas of skewness and kurtosis (only through diagrams), Exploratory Data Analysis. (8)

Understanding bivariate data: Paired data and ideas (without mathematical details) of different measures of associations, primarily Pearson's correlation coefficient, Spearman's Rank correlation (no tie), measures of association of attributes through contingency table, two-variable linear regression and multiple (three-variable only) linear regression (without derivation of the regression coefficients' formulae). (8)

Statistical Inference (*testing of hypothesis*): Basic idea of binomial and normal populations (graphical idea only, derivation of the properties excluded). Concepts of hypotheses, knowledge on test statistic and decision making in terms of critical value and p-value for some standard testing problems like test for proportion/proportions, mean based on single (normal) sample, test on comparing means based on two-sample and paired sample data. (7)

Miscellaneous discussion: Applications of one-way and two-way ANOVA with one observation per cell (without derivation and details) assuming normality, Kruskal-Wallis test (without derivation and details), sample size determination, estimation of population mean and variability for finite population, idea and application of logistic regression for binary response data. (7)

STAT-H-IDC1-1-P **1 Credit**

(Statistics for Practitioners) **PRACTICAL**

List of Suggested Practical

- Measures of mean, median, mode, range, QD, SD, CV for univariate data case.
- Fitting of linear regression on bivariate and on three-variable multivariate data, measures of Pearsons correlation coefficients, Spearman's Rank correlation, measures of association of attributes through contingency table.
- Tests for proportion/proportions, tests of means for single sample, two-sample, and paired sample data on normal response using p-value approach.
- Applications of ANOVA and Kruskal-Wallis test.
- Sample size determination, estimation of population mean and variability for finite population.
- Fitting of logistic regression for binary response data.

Reference Books:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata.
- Das, N.G.: Statistical Methods, Vol I, Tata McGraw Hill Pub. Co. Ltd.
- Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis, PHI.
- Hardle W. and Simar, L.: Applied Multivariate Statistical Analysis.
- Kutner, M.H. et.al.: Applied Linear Statistical Models.
- Belsley D.A. et.al.: Regression Diagnostics.
- Draper N.R. and Smith, H.: Applied Regression Analysis.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

SEMESTER - II

STATISTICS MAJOR

STAT-H-CC2-2-Th **3 Credits**

(Descriptive Statistics II & Probability II) **THEORY**

Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intraclass correlation.

Rank correlation: Spearman's and Kendall's measures. (15)

Analysis of Categorical Data: Contingency table, independence & association of attributes. (5)

Random Variables: Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (without proof), probability mass function (p.m.f.) and probability density function (p.d.f.). Expectation and Variance.

Standard probability distributions: Discrete Uniform, Binomial, Poisson, and Normal. (25)

STAT-H-CC2-2-P **1 Credit**

(Descriptive Statistics II & Probability II) **PRACTICAL**

List of Suggested Practical

- Problems based on analysis of bivariate data.
- Problems based on measures of rank correlation.
- Problems based on analysis of categorical data.
- Finding expectation, variance from a given probability distribution.
- Fitting of binomial distributions for n and p = q = 1/2.
- Fitting of binomial distributions for given n and p.
- Fitting of binomial distributions after computing mean and variance.
- Fitting of Poisson distributions for given value of mean.
- Fitting of Poisson distributions after computing mean.
- Application problems based on binomial distribution.
- Application problems based on Poisson distribution.
- Problems based on area property of normal distribution.
- To find the ordinate for a given area for normal distribution.

- Application based problems using normal distribution.
- Fitting of normal distribution when parameters are given.
- Fitting of normal distribution when parameters are not given.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, The World Press, Kolkata.
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- Agresti, A.: Analysis of Ordinal Categorical Data, 2^{nd} Edition, Wiley.
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- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Hogg, R.V., Tanis, E.A. and Rao J.M.: Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
- Myer, P.L.: Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2^{nd} Edn. (Reprint) John Wiley and Sons.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STAT-H-SEC2-2-Th **2 credits**

(Artificial Intelligence for Everyone) **THEORY**

Unit 1: Introduction to Artificial Intelligence (6 Lectures)

- Definition and scope of AI
- Historical overview and key milestones
- Differentiating AI from human intelligence

Unit 2: AI Subfields and Technologies (6 Lectures)

- Machine learning: Supervised, unsupervised, and reinforcement learning
- Deep learning and neural networks
- Natural language processing (NLP) and computer vision

Unit 3: Applications of AI (8 Lectures)

- AI in healthcare: Diagnosis, treatment, and medical imaging
- AI in finance: Fraud detection, algorithmic trading, and risk assessment
- AI in transportation: Autonomous vehicles and traffic optimization
- AI in customer service and chatbots
- AI in education: Personalized learning and intelligent tutoring systems

Unit 4: Ethical and Social Implications of AI (5 Lectures)

- Bias and fairness in AI systems
- Privacy and data protection concerns
- Impact of AI on employment and the workforce
- AI and social inequality

Unit 5: Other Important Issues

- Ethical guidelines and responsible AI practices
- AI and Innovation
- Emerging trends and future directions in AI
- AI and creativity: Generative models and artistic applications

STAT-H-SEC2-2-TU **2 credits**

(Artificial Intelligence for Everyone) **TUTORIAL**

Term Paper In lieu of Tutorial paper: Students are required to submit a report which can be based on any topic as given below or as prescribed by the respective faculty/teachers.

Suggested problems for the reports (Term Paper) on Artificial intelligence (A.I.):

- A comparative study on Human Intelligence and Artificial Intelligence in Man-Made Machines.
- Chatbot Development for customer service support and integration of NLP for realistic/human type interactions.
- Development of a sentiment analysis tool that can classify and analyze the sentiment (positive, negative, neutral) in social media posts, reviews, or any text data.
- Use of AI in Image Recognition and Classification.
- Application of Linear regression and A.I/Machine learning on house price prediction- Estimating the selling price of a house based on its features, location, and market trends.
- Application of Linear regression and A.I/Machine learning on the data of Climate prediction.
- Application of Linear regression and A.I/Machine learning on the data of Bank related works.
- Application of Linear regression and A.I/Machine learning on Sales Forecasting: Predicting future sales based on historical sales data and trends.
- Application of Linear regression and A.I/Machine learning on Weather Forecasting, predicting future weather conditions by analyzing historical weather data.
- Application of Linear regression and A.I/Machine learning on Forecasting future energy usage based on past consumption patterns and environmental factors.
- Application of Linear regression and A.I/Machine learning on Risk Assessment: Predicting the likelihood of an event occurring, such as loan default or insurance claims, based on historical data and risk factors.
- Application of Linear regression and A.I/Machine learning on Health Outcome Prediction: Estimating patient outcomes or disease progression based on historical medical data and patient characteristics.
- Different types of Machine learning algorithms and its applications.
- Smart home automation solutions.
- Using AI in autonomous ground and Aerial vehicles.
- Application of AI in healthcare industry, Industrial automation, Smart farming and Internet of Things (IoT).
- Use of AI and its impact in future of education.
- Application of AI in Robotics and Computer Vision.

Note: *The topics listed here are merely examples. Students are encouraged to write a term paper in the form of a report on subjects not limited to these topics; additional suggestions can be provided by teachers, faculty members, or the department*.

STATISTICS MINOR

STAT-H-MC2-2-Th **3 Credits**

(Descriptive Statistics II & Probability II) **THEORY**

Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intraclass correlation.

Rank correlation: Spearman's and Kendall's measures. (15)

Analysis of Categorical Data: Contingency table, independence & association of attributes. (5)

Random Variables: Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (without proof), probability mass function (p.m.f.) and probability density function (p.d.f.). Expectation and Variance.

Standard probability distributions: Discrete Uniform, Binomial, Poisson, and Normal. (25)

STAT-H-MC2-2-P **1 Credit**

(Descriptive Statistics II & Probability II) **PRACTICAL**

List of Suggested Practical

- Problems based on analysis of bivariate data.
- Problems based on measures of rank correlation.
- Problems based on analysis of categorical data.
- Finding expectation, variance from a given probability distribution.
- Fitting of binomial distributions for n and p = q = 1/2.
- Fitting of binomial distributions for given n and p.
- Fitting of binomial distributions after computing mean and variance.
- Fitting of Poisson distributions for given value of mean.
- Fitting of Poisson distributions after computing mean.
- Application problems based on binomial distribution.
- Application problems based on Poisson distribution.
- Problems based on area property of normal distribution.
- To find the ordinate for a given area for normal distribution.
- Application based problems using normal distribution.
- Fitting of normal distribution when parameters are given.
- Fitting of normal distribution when parameters are not given.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Agresti, A.: Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, 4th Edition, W. W. Norton & Company.
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- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
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- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Hogg, R.V., Tanis, E.A. and Rao J.M.: Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
- Myer, P.L.: Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STATISTICS INTERDISCIPLINARY

STAT-H-IDC2-2-Th **2 Credits**

(Statistics for Practitioners) **THEORY**

Understanding univariate data: Variable, notion of population and sample, different types of data, methods of collecting primary and secondary data, presentation of data, summary measures on data with central tendency (arithmetic mean, median, mode), dispersion (range, quartile deviation, standard deviation, coefficient of variation), ideas of skewness and kurtosis (only through diagrams), Exploratory Data Analysis. (8)

Understanding bivariate data: Paired data and ideas (without mathematical details) of different measures of associations, primarily Pearson's correlation coefficient, Spearman's Rank correlation (no tie), measures of association of attributes through contingency table, two-variable linear regression and multiple (three-variable only) linear regression (without derivation of the regression coefficients' formulae). (8)

Statistical Inference (*testing of hypothesis*): Basic idea of binomial and normal populations (graphical idea only, derivation of the properties excluded). Concepts of hypotheses, knowledge on test statistic and decision making in terms of critical value and p-value for some standard testing problems like test for proportion/proportions, mean based on single (normal) sample, test on comparing means based on two-sample and paired sample data. (7)

Miscellaneous discussion: Applications of one-way and two-way ANOVA with one observation per cell (without derivation and details) assuming normality, Kruskal-Wallis test (without derivation and details), sample size determination, estimation of population mean and variability for finite population, idea and application of logistic regression for binary response data. (7)

STAT-H-IDC2-2-P **1 Credit**

(Statistics for Practitioners) **PRACTICAL**

List of Suggested Practical

- Measures of mean, median, mode, range, QD, SD, CV for univariate data case.
- Fitting of linear regression on bivariate and on three-variable multivariate data, measures of Pearsons correlation coefficients, Spearman's Rank correlation, measures of association of attributes through contingency table.
- Tests for proportion/proportions, tests of means for single sample, two-sample, and paired sample data on normal response using p-value approach.
- Applications of ANOVA and Kruskal-Wallis test.
- Sample size determination, estimation of population mean and variability for finite population.
- Fitting of logistic regression for binary response data.

Reference Books:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata.
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SEMESTER - III

STATISTICS MAJOR

STAT-H-CC3-3-Th **3 Credits**

(Real Analysis I) **THEORY**

Introduction to Real Numbers

Axiomatic definition of the real number system: Field Axioms, Order Axioms, Archimedean property: Intuition, bounded and unbounded sets, Supremum, Infimum, axiom of LUB. Rational and Irrational Numbers, Absolute value function. Intervals: Types of bounded, Unbounded Intervals. Neighbourhoods: ε-Neighbourhood, Open Neighbourhood. (10)

Sequences and Series

Definition of sequences, limits and Convergence: Uniqueness of Limits, Algebra of Limits, Squeeze Theorem. Monotone sequences and Monotone Convergence Theorem (MCT). Subsequences: Properties, Cauchy sequences. Bolzano-Weierstrass theorem. Series of real numbers: Cauchy criterion, Convergence tests: Comparison Test, Ratio Test, Root Test, Alternating Series Test (Leibniz's Test) (statements). Absolute and conditional convergence. (12)

Functions, Limits and Continuity

Bounded and unbounded functions, Monotone functions, Limits of functions, ε-δ definition, one-sided limits. Properties of limits: Uniqueness of Limits, Algebra of Limits: Sequential criterion, infinite limits, limits of +- infinity. Continuous functions: definition of continuity at a point (sequential characterization), continuity on a set, Algebraic Properties, Composition. Continuity on intervals, extreme value theorem. Intermediate value theorem. (10)

Differentiation

Definition of the derivative; interpretations of the derivative. Criteria for extrema. Theorems involving differentiable functions: Rolle's Theorem, Lagrange's Mean Value Theorem (MVT), Cauchy's Mean Value Theorem, Higher order derivatives, Taylor's Theorem (Statement only). (8)

Integration

Riemann integration: Definition, properties: Linearity, Additivity, Interval Reversal, Monotonicity, Integrability of monotone functions, continuous functions (without proof), Fundamental theorem of calculus. Improper integrals. (5)

STAT-H-CC3-3-TU **1 Credit**

(Real Analysis I) **TUTORIAL**

Reference Books

- Malik S.C. and Savita Arora: Mathematical Analysis, Second Edition, Wiley Eastern Limited, New Age International Limited, New Delhi.
- Somasundram, D. And Chaudhary, B.: A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi.
- Gupta S.L. and Nisha Rani: Principles of Real Analysis, Vikas Publ. House Pvt. Ltd., New Delhi.
- Apostol, T.M: Mathematical Analysis, Second Edition, Narosa Publishing House, New Delhi.
- Shanti Narayan: A course of Mathematical Analysis, 12th revised Edition, S. Chand & Co. (Pvt.) Ltd., New Delhi.
- Singal, M.K. and Singal A.R: A First Course in Real Analysis, 24th Edition, R. Chand& Co., New Delhi.
- Bartle, R. G. and Sherbert, D. R.: Introduction to Real Analysis (3rd Edition), John Wiley and Sons (Asia) Pte. Ltd., Singapore.
- Ghorpade, Sudhir R. and Limaye, Balmohan V.: A Course in Calculus and Real Analysis, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint.
- Chakraborty, Arnab: Real Analysis, volumes 1,2,3, second edition. Sarat Book House.
- Walter Rudin: Principles of Mathematical Analysis
- Stephen Abbott: Understanding Analysis
- Robert G. Bartle and Donald R. Sherbert: Introduction to Real Analysis

STAT-H-CC4-3-Th **3 Credits**

(Statistical Inference I) **THEORY**

Basic concepts of Statistical Inference: population & sample, parameter & statistic, population distribution and sampling distribution. Point estimation, interval estimation and testing of hypothesis. Three useful distributions for statistical Inference: χ^2, t and F (derivations excluded). (5)

Point Estimation: Concepts of estimation, requirements of a good estimator, notions of mean square error, unbiasedness, bias-variance trade off, best linear unbiasedness and minimum variance unbiasedness. Properties of uniformly minimum variance unbiased estimators (UMVUE). Comparison of Estimators, Efficiency. Methods of Estimation: Method of moments, method of maximum likelihood estimation and statements of their small sample properties. Point estimators of the parameters of Binomial, Poisson, and univariate Normal distributions. (15)

Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, p-value. Exact tests and confidence intervals: classical and p-value approaches. Tests relating to Binomial and Poisson distributions, Fisher's exact test. Chi-square tests for association, homogeneity and goodness of fit. Tests of hypotheses for the parameters of normal distribution (one sample and two sample problems), paired t-test. Combination of probabilities in tests of significance. (20)

Interval Estimation: Confidence Interval and Confidence Coefficient, Exact confidence interval for mean(s) and variance(s) for one and two sample problems under the Normal set-up. (5)

STAT-H-CC4-3-P **1 Credit**

(Statistical Inference I) **PRACTICAL**

List of Suggested Practical

- Maximum Likelihood Estimation.
- Estimation by the method of moments.
- Test of significance for single proportion and difference of two proportions.
- Test of significance for single Poisson mean and difference of two Poisson means.
- Chi square tests for association, homogeneity and goodness of fit.
- Test of significance and confidence intervals for single mean and difference of two means.
- Test of significance and confidence intervals for single variance and ratio of two variances.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory, Vol-1. World Press.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Hogg, R.V., Tanis, E.A. and Zimmerman, D. L.: Probability and Statistical Inference. Pearson Education.
- Johnson, R.A. and Bhattacharya, G.K.: Statistics-Principles and Methods, 4th Edn. John Wiley and Sons.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint). Tata McGraw-Hill.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Gupta, S.C. and Kapoor, V.K. (2020): Fundamentals of Mathematical Statistics. Sultan Chand and Sons.
- Ramachandran, K.M. and Tsokos, C.P.: Mathematical Statistics with Applications. Academic Press.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STAT-H-SEC3-3-P **4 Credits**

(Introduction to R) **PRACTICAL**

Introduction to R:

Overview of R: History and Applications. Installation and Setup (R and RStudio). Basic R Syntax and Commands: Comments, Assignment, Printing Output, installing a Package, Loading a Package. R as a Calculator: Addition, Subtraction, Multiplication, Division, Exponentiation, Modulus (Remainder), Integer Division, Order of Operations (PEMDAS/BODMAS).

Data Types and Structures:

Basic Data Types (Numeric, Integer, Character, Logical). Vectors, Matrices, Arrays: Creation, Operations, Indexing. Lists and Data Frames: Structure, creating a list, Accessing Elements, adding an element, removing an element, creating a data frame, accessing columns, accessing rows, accessing specific elements, adding a new column, removing a column, Adding a new row. Factors and Categorical Data: Creating a factor, checking levels, converting a vector to a factor, creating an ordered factor, converting factor to numeric, Converting factor to character, Data frame with a factor variable.

Data Import and Export:

Reading Data from Files (CSV, Excel, etc.): Basic usage, Example with options, reading an Excel file Using “readxl”, “openxlsx” packages, Example with options, Reading TXT Files, Reading Data from R's Built-in Datasets. Writing Data to Files: Writing the data frame to a CSV file, Writing the data frame to an Excel file Using “writexl”, “openxlsx” packages, Writing the text vector to a file. Checking for missing values in a vector, removing rows with missing values, removing columns with missing values, Mean/Median/Mode Imputation, Handling “NA”s in common functions.

Basic Data Manipulation:

Subsetting Data: Extracting a specific column of a Data Frame, Extracting multiple columns of a Data Frame, Extracting specific rows and columns of a Data Frame, Extracting specific rows only of a Data Frame, Extracting rows of a Data Frame that meet a condition, Combine multiple conditions, Extracting specific elements of a Vector, Extracting elements of a Vector that meet a condition, Finding indices where the condition is true Using the “which()” Function. Sorting and Ordering Data: Sorting Vectors in Ascending Order, Descending Order, ordering a data frame by one or more columns use the “order()” function, Using “dplyr” package for Sorting. Merging and Joining Data Frames: Using “merge()” Function, Using “dplyr”, “data.table” Packages.

Data Visualization:

Base R Graphics (Histograms, Boxplots, Scatterplots): Creating histograms, Boxplots, Scatterplots. Introduction to ggplot. Customizing Plots (Titles, Labels, Legends): Basic Plot Customization like adding X-axis label, Y-axis label, Colour of points, Type of point, Adding Legends. Creating Multi-panel Plots: Using "par()" function for Base R Graphics.

Programming Basics:

Functions and Loops (for, while): basic syntax for defining a function, calling the function, For Loop, While Loop, using loops inside functions or vice versa. Conditional Statements (if, else): "if" Statement, "if-else" Statement, chaining multiple conditions using "if-else if-else" Statement, Nested "if" Statements, applying conditions to each element of a vector using "ifelse". Simulation in the context of Loop, Acceptance-Rejection method, illustration of repeated sampling and large sample properties through simulation. Numerical integration, Numerical solution of equations.

Statistical Analysis with R:

Descriptive Statistics: Mean, Median, Standard Deviation, Variance, Summary Statistics, Quantiles, Range, Interquartile Range. Probability Distributions and Random Number Generation: Density, Cumulative Distribution Function, Quantile Function, Random Generation from Normal Distribution, Binomial Distribution, Poisson Distribution, Exponential Distribution, and Uniform Distribution, Setting Seed for Reproducibility. Hypothesis Testing (t-tests, Chi-square tests): One-sample t-test, Two-sample t-test (independent), Paired t-test, Chi-square test for independence between two categorical variables. Correlation and Regression Analysis: Pearson Correlation, Spearman Correlation, Simple Linear Regression, Plotting the data and regression line, Multiple Linear Regression. ANOVA (Analysis of Variance): Conducting one-way ANOVA, Viewing ANOVA table, conducting two-way ANOVA with interaction, Viewing ANOVA table.

Advanced Data Manipulation:

Applying Functions to Data (apply, lapply, sapply).

Reference Books

- Gardener, M (2012) Beginning R: The Statistical Programming Language, Wiley Publications
- Braun W J, Murdoch D J (2007): A First Course in Statistical Programming with R. Cambridge University Press. New York
- A simple introduction to R by Arnab Chakraborty
  (freely available at http://www.isical.ac.in/~arnabc/)
- R for beginners by Emmanuel Paradis
  (freely available at https://cran.rproject.org/doc/contrib/Paradisrdebuts_en.pdf)
- Michael J. Crawley (2012): The R Book, Wiley
- Garrett Grolemund (2014): Hands-On Programming with R, O'Reilly Media

STATISTICS MINOR

STAT-H-MC1-3-Th **3 Credits**

(Descriptive Statistics I & Probability I) **THEORY**

Statistics: Definition and scope. Concepts of statistical population and sample.
Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous.
Scales of measurement: nominal, ordinal, interval and ratio.
Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays. (10)

Measures of Central Tendency: Mean, Median, Mode.
Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation, Ginis Coefficient, Lorenz Curve. Moments, skewness and kurtosis. Quantiles and measures based on them. Box Plot. Outliers. (15)

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability: classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (20)

STAT-H-MC1-3-P **1 Credit**

(Descriptive Statistics I & Probability I) **PRACTICAL**

List of Suggested Practical

- Diagrammatic representation of data.
- Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations, stem and leaf plot.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation.
- Problems based on moments, skewness and kurtosis.
- Problems related to quantiles and measures based on them, construction of box plot.
- Application problems based on Classical Definition of Probability.
- Application problems based on Bayes' Theorem.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STATISTICS INTERDISCIPLINARY

STAT-H-IDC3-3-Th **2 Credits**

(Statistics for Practitioners) **THEORY**

Understanding univariate data: Variable, notion of population and sample, different types of data, methods of collecting primary and secondary data, presentation of data, summary measures on data with central tendency (arithmetic mean, median, mode), dispersion (range, quartile deviation, standard deviation, coefficient of variation), ideas of skewness and kurtosis (only through diagrams), Exploratory Data Analysis. (8)

Understanding bivariate data: Paired data and ideas (without mathematical details) of different measures of associations, primarily Pearson's correlation coefficient, Spearman's Rank correlation (no tie), measures of association of attributes through contingency table, two-variable linear regression and multiple (three-variable only) linear regression (without derivation of the regression coefficients' formulae). (8)

Statistical Inference (*testing of hypothesis*): Basic idea of binomial and normal populations (graphical idea only, derivation of the properties excluded). Concepts of hypotheses, knowledge on test statistic and decision making in terms of critical value and p-value for some standard testing problems like test for proportion/proportions, mean based on single (normal) sample, test on comparing means based on two-sample and paired sample data. (7)

Miscellaneous discussion: Applications of one-way and two-way ANOVA with one observation per cell (without derivation and details) assuming normality, Kruskal-Wallis test (without derivation and details), sample size determination, estimation of population mean and variability for finite population, idea and application of logistic regression for binary response data. (7)

STAT-H-IDC3-3-P **1 Credit**

(Statistics for Practitioners) **PRACTICAL**

List of Suggested Practical

- Measures of mean, median, mode, range, QD, SD, CV for univariate data case.
- Fitting of linear regression on bivariate and on three-variable multivariate data, measures of Pearsons correlation coefficients, Spearman's Rank correlation, measures of association of attributes through contingency table.
- Tests for proportion/proportions, tests of means for single sample, two-sample, and paired sample data on normal response using p-value approach.
- Applications of ANOVA and Kruskal-Wallis test.
- Sample size determination, estimation of population mean and variability for finite population.
- Fitting of logistic regression for binary response data.

Reference Books:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata.
- Das, N.G.: Statistical Methods, Vol I, Tata McGraw Hill Pub. Co. Ltd.
- Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis, PHI.
- Hardle W. and Simar, L.: Applied Multivariate Statistical Analysis.
- Kutner, M.H. et.al.: Applied Linear Statistical Models.
- Belsley D.A. et.al.: Regression Diagnostics.
- Draper N.R. and Smith, H.: Applied Regression Analysis.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

SEMESTER - IV

STATISTICS MAJOR

STAT-H-CC5-4-Th **3 Credits**

(Linear Algebra) **THEORY**

Vector Algebra:

Vectors as points in Euclidean spaces; subspaces of R^n; linear combinations and span; generators of subspaces; linear dependence and independence (of finite sets of vectors); intersections, sums and direct sums of subspaces; complements and projections; basis, characterizations of bases, extensions of linearly independent sets to bases; dimension, connection between dimensions of a pair of subspaces and those of their sum and intersection; (Euclidean) norm and inner product; triangle inequality and Cauchy-Schwarz inequality, orthogonality and orthonormality, Gram-Schmidt process, orthocomplements and orthogonal projections. (20)

Matrix Algebra:

Linear transformations and matrices (w.r.t. standard bases), examples, properties, transposes, compositions, elementary operations, diagonal, triangular, symmetric and skew-symmetric matrices, Echelon matrix, Kronecker product, range and rank, null space and nullity, rank-nullity theorem, ranks of products and sums, row and column spaces, invertibility, operations with partitioned matrices, orthogonal matrices, construction of non-singular and orthogonal matrices with given rows/columns. (12)

Trace and determinant of square matrices, properties, computations. (4)

Systems of simultaneous linear equations: consistency, solution spaces of homogeneous and non-homogeneous systems, existence and uniqueness of solutions, methods of solution. (4)

Eigenvalues and eigenvectors of square matrices, multiplicities, properties, characteristic polynomial, similarity, spectral decomposition of symmetric matrices. Quadratic forms, connections with eigenvalues, idempotent matrices. Cayley-Hamilton Theorem (Statement only) (5)

STAT-H-CC5-4-P **1 Credit**

(Linear Algebra) **PRACTICAL**

List of Suggested Practical

- Problems related to vectors and vector spaces – linear dependence and independence, spanning set and bases, orthogonality, projections.
- Problems on matrix operations and reductions.
- Problems on linear transformations.
- Problems on determinants and inverses.
- Problems on rank of matrices.
- Problems on solutions to system of linear equations.
- Problems on quadratic forms.
- Problems on eigen values and eigen vectors.

Reference Books

- Lay David C.: Linear Algebra and its Applications, Addison Wesley.
- Schaum's Outlines: Linear Algebra, Tata McGraw-Hill Edition, 3rd Edition.
- Krishnamurthy, V., Mainra V.P. and Arora J.L.: An Introduction to Linear Algebra (II, III, IV, V).
- Biswas, S.: A Textbook of Matrix Algebra, New Age International.
- Gupta, S.C.: An Introduction to Matrices (Reprint). Sultan Chand & Sons.
- Artin, M: Algebra. Prentice Hall of India.
- Datta, K.B: Matrix and Linear Algebra. Prentice Hall of India Pvt. Ltd.
- Hadley, G: Linear Algebra. Narosa Publishing House (Reprint).
- Searle, S.R.: Matrix Algebra Useful for Statistics. John Wiley &Sons.
- Chakraborty, Arnab: Linear Algebra, First Edition. Sarat Book House.
- Goon A.M.: Vectors and Matrices, World Press
- Das Roy, A. and Roy, D.: Linear Algebra with Application to Statistics, World Press

STAT-H-CC6-4-Th **3 Credits**

(Probability III) **THEORY**

Moments, Quantiles, Skewness and Kurtosis (including discussions of these measures for Binomial, Poisson and Univariate Normal Distributions). Probability inequalities (Markov's and Chebyshev's). Generating functions – probability generating function and moment generating function. Characteristic function (definition only). (10)

Discrete probability distributions: Uniform, Geometric, negative binomial, hypergeometric. Limiting/approximation cases. Truncated distributions. (5)

Continuous probability distributions: uniform, exponential, Cauchy, beta, gamma, lognormal, logistic, double exponential, Pareto and Weibull distributions along with their properties. Truncated distributions. (15)

Two dimensional random variables: joint, marginal and conditional distributions, properties of c.d.f., independence of variables, Theorems on sum and product of expectations of random variables, Conditional Expectation, Correlation and Regression. (10)

Trinomial distribution and its properties. Bivariate Normal Distribution and its properties. (5)

STAT-H-CC6-4-P **1 Credit**

(Probability III) **PRACTICAL**

List of Suggested Practical

- Fitting of negative binomial distribution.
- Application problems based on geometric, negative binomial and hypergeometric distributions.
- Fitting of continuous distributions.
- Application Problems based on continuous distributions.
- Application based Problems on trinomial distributions.
- Application based Problems on bivariate normal distributions.

Reference Books

- Hoel, P.G., Port, S.C. and Stone, C.J.: Introduction to Probability Theory. Houghton Mifflin Company.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Mood A.M, Graybill F.A. and Boes D.C: Introduction to the Theory of Statistics, McGraw Hill.
- Dasgupta, A.: Fundamentals of Probability – A First Course. Springer.
- Goon A.M., Gupta M.K. and Das Gupta. B.: Outline of Statistics, Vol. 1, World Press, Calcutta.
- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Casella, G. and Berger R.L.: Statistical Inference, 2nd Edition. Thomson Learning.
- Pitman, J.: Probability. Springer.
- Mukhopadhyay, P.: Mathematical Statistics. Books and Allied Publishers, Kolkata.
- Mukhopadhyay, N.: Probability and Statistical Inference. Marcel Dekker, New York.
- Chandra, T.K. and Chatterjee, D.: A First Course in Probability. Alpha Science.
- Cacoullos, T.: Exercises in Probability. Springer Verlag.
- Johnson, N.L., Kotz, S. and Balakrishnan, N.: Continuous Univariate Distributions, Volume 1 and 2. John Wiley and Sons.
- Johnson, N.L., Kemp, A.W. and Kotz, S.: Univariate Discrete Distributions. John Wiley and Sons.
- Ross, S.: A First Course in Probability. Pearson Education.

STAT-H-CC7-4-Th **3 Credits**

(Sampling Distributions and Statistical Inference II) **THEORY**

Concepts of random sampling. Sampling distribution of a statistic and its standard error. Distributions of statistics – illustrations using different distributions, reproductive properties of the distributions. *Order Statistics*: Introduction, distribution of the *r*-th order statistic, smallest and largest order statistics. Joint distribution of order statistics, distribution of sample median. (10)

Derivation of some standard sampling distributions: χ^2, t and F, sample mean and variance of a random sample from a univariate normal population, distributions of sample means, sample variances and sample correlation coefficient (null case) of a random sample from a bivariate normal population, distribution of the simple regression coefficient (for non-stochastic independent variable). (10)

Point Estimation: Sufficiency, factorization theorem (proof for discrete case only). Fisher's information (for single parameter only). Cramer-Rao inequality and minimum variance bound (MVB) estimators, Rao-Blackwell theorem and its applications. (10)

Theory of hypothesis testing: Test function, randomized and non-randomized tests, most powerful (MP) test, uniformly most powerful (UMP) test, Neyman - Pearson Lemma (statement and proof of sufficiency part only) and its applications to construct MP and UMP tests, uniformly most powerful unbiased (UMPU) tests (definition only).
Likelihood ratio test, properties of likelihood ratio test (without proof). (10)

Interval Estimation: Confidence intervals, Concepts of Uniformly Most Accurate (UMA) confidence sets, relationship with tests of hypotheses. (5)

STAT-H-CC7-4-P **1 Credit**

(Sampling Distributions and Statistical Inference II) **PRACTICAL**

List of Suggested Practical

- Most powerful critical region.
- Uniformly most powerful critical region.
- Unbiased critical region.
- Power curves.
- Confidence intervals and UMA confidence sets.
- Likelihood ratio tests for simple null hypothesis against simple alternative hypothesis.
- Likelihood ratio tests for simple null hypothesis against composite alternative hypothesis.

Reference Books:

- Goon A.M., Gupta M.K.: Das Gupta. B.: An Outline of Statistical Theory, Vol. I & II, World Press, Calcutta.
- Rohatgi V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
- Miller, I. and Miller, M.: John E. Freund's Mathematical Statistics (6th addition, low price edition), Prentice Hall of India.
- Mood A.M, Graybill F.A. and Boes D.C: Introduction to the Theory of Statistics, McGraw Hill.
- Casella, G. and Berger R.L.: Statistical Inference, 2nd Edn. Thomson Learning.
- Bhattacharya, P. K. and Burman, P.: Theory and Methods of Statistics. Academic Press.
- Mukhopadhyay, N.: Probability and Statistical Inference. Marcel Dekker, New York.
- Kale, B. K.: A First Course on Parametric Inference. Narosa Publishing House.
- Lehmann, E. L. and Romano, J. P.: Testing Statistical Hypothesis, 3rd Edition. Springer.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Mukhopadhyay, P.: Mathematical Statistics. Books and Allied Publishers, Kolkata.
- Rajagopalan, M. and Dhanavanthan, P.: Statistical Inference. Prentice Hall India.
- Srivastava, M.K. and Srivastava, N.: Statistical Inference: Testing of Hypotheses. Prentice Hall India.

STAT-H-CC8-4-Th **3 Credits**

(Design of Experiments I and Sample Survey I) **THEORY**

Design of Experiments I:

Analysis of Variance: Factors, types and effects; Fixed, random and mixed effects models; Analysis of one-way and two-way classified data with equal number of observations in each cell (Fixed Effects Models only). (10)

Experimental designs: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments (Fisher). (2)

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model, Applications of the techniques of ANOVA to the analysis of the above designs. Missing plot techniques in RBD and LSD. Uniformity trial experiments and comparison of designs. (10)

Sample Survey I:

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, random numbers, procedure of selecting a sample, estimates of population mean, total and proportion, standard errors of these estimates, estimates of their standard errors. (15)

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. (4)

Two-stage sampling (with primary units of equal size and equal selection probability at each stage): unbiased estimation of population mean and total. Ideas of snowball sampling, purposive sampling. (4)

STAT-H-CC8-4-P **1 Credit**

(Design of Experiments I and Sample Survey I) **PRACTICAL**

List of Suggested Practical

- Analysis of Variance of a one-way classified data (fixed effects model).
- Analysis of Variance of a two-way classified data with one observation per cell (fixed effects model).
- Analysis of Variance of a two-way classified data with more than one observation per cell (fixed effects model).
- Analysis of a CRD.
- Analysis of an RBD.
- Analysis of an LSD.
- Analysis of an RBD with one missing observation.
- Analysis of an LSD with one missing observation.
- To select a simple random sample with and without replacement.
- Simple random sampling – estimation of population mean, total and proportion; estimation of related standard error.
- Estimate the sample size for SRSWOR.
- Stratified Sampling –estimation of population mean and total, allocation of sample to strata by proportional and Neyman's methods, Comparison of the efficiencies of the above two methods relative to SRS.
- Estimation of gain in precision in stratified sampling.
- Two-stage Sampling – estimation of population mean and total.

Reference Books:

- Renchner, A. C. And Schaalje, G. B.: Linear Models in Statistics (Second edition), John Wiley and Sons.
- Scheffe, H.: The Analysis of Variance, John Wiley.
- Cochran, W.G. and Cox, G.M.: Experimental Design. Asia Publishing House.
- Das, M.N. and Giri, N.C.: Design and Analysis of Experiments. Wiley Eastern Ltd.
- Kempthorne, O.: The Design and Analysis of Experiments. John Wiley.
- Montgomery, D. C.: Design and Analysis of Experiments, John Wiley.
- Wu, C. F. J. And Hamada, M.: Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
- Dean, A.M. and Voss, D.: Design and Analysis of Experiments. Springer Texts in Statistics.
- Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory, Vol-II, World Press, Calcutta.
- Goon A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol-II, World Press.
- Cochran, W.G.: Sampling Techniques (3rd Ed.), Wiley Eastern.
- Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok, C.: Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Murthy, M.N.: Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P.: Sample Survey Theory, Narosa Publishing House.

STATISTICS MINOR

STAT-H-MC2-4-Th **3 Credits**

(Descriptive Statistics II & Probability II) **THEORY**

Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intraclass correlation.

Rank correlation: Spearman's and Kendall's measures. (15)

Analysis of Categorical Data: Contingency table, independence & association of attributes. (5)

Random Variables: Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (without proof), probability mass function (p.m.f.) and probability density function (p.d.f.). Expectation and Variance.

Standard probability distributions: Discrete Uniform, Binomial, Poisson, and Normal. (25)

STAT-H-MC2-4-P **1 Credit**

(Descriptive Statistics II & Probability II) **PRACTICAL**

List of Suggested Practical

- Problems based on analysis of bivariate data.
- Problems based on measures of rank correlation.
- Problems based on analysis of categorical data.
- Finding expectation, variance from a given probability distribution.
- Fitting of binomial distributions for n and p = q = 1/2.
- Fitting of binomial distributions for given n and p.
- Fitting of binomial distributions after computing mean and variance.
- Fitting of Poisson distributions for given value of mean.
- Fitting of Poisson distributions after computing mean.
- Application problems based on binomial distribution.
- Application problems based on Poisson distribution.
- Problems based on area property of normal distribution.
- To find the ordinate for a given area for normal distribution.
- Application based problems using normal distribution.
- Fitting of normal distribution when parameters are given.
- Fitting of normal distribution when parameters are not given.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Agresti, A.: Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, 4th Edition, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Hogg, R.V., Tanis, E.A. and Rao J.M.: Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
- Myer, P.L.: Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

SEMESTER - V

STATISTICS MAJOR

STAT-H-CC9-5-Th **3 Credits**

(Multivariate Analysis I) **THEORY**

Introduction to Multivariate Analysis: Concept of multivariate data. Notation and data structures (mean vector, dispersion and correlation matrices). Multiple regression, multiple correlation and partial correlation – their properties and related results. (12)

Random Vector: Joint Probability mass and density functions, Distribution Function, Mean vector, Dispersion matrix and Correlation Matrix, Marginal and Conditional Distributions, Independence of random vectors, Ellipsoid of Concentration, Multiple Regression, Multiple Correlation, Partial Correlation. Linear combinations of random variables and vectors. (17)

Canonical correlation: Definition, Conceptual overview, Mathematical formulation and computations, canonical weights and scores. Applications of canonical correlations. (4)

Multivariate Distributions: Multinomial, Dirichlet, Multivariate Normal distributions and their properties.

Sampling from multivariate normal distribution, MLEs, distributions and independence of sample mean vector and variance-covariance matrix.

Tests for Multiple and partial correlation coefficients. Tests for regression coefficients in multiple regression model. (12)

STAT-H-CC9-5-P **1 Credit**

(Multivariate Analysis I) **PRACTICAL**

List of Suggested Practical

- Problems on Multiple Linear Regression.
- Problems on Multiple and Partial Correlation Coefficients.
- Problems based on Tests for Multiple Correlation.
- Problems based on Tests for Partial Correlation.
- Problems on canonical correlations.
- Problems relating to Multinomial Distribution.
- Problems relating to Multivariate Normal Distribution.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2013): Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Anderson, T.W. (2003): An Introduction to Multivariate Statistical Analysis, 3rd Edn., John Wiley
- Muirhead, R.J. (1982): Aspects of Multivariate Statistical Theory, John Wiley.
- Mukhopadhyay, P. (1996): Mathematical Statistics. New Central Book Agency.
- Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Rencher, A.C. and Christensen, W.F. (2012). Methods of Multivariate Analysis. Wiley.
- Mardia, K.V., Kent, J.T. and Bibby, J.M. (1979). Multivariate Analysis. Academic Press.
- Johnson, R.A. and Wichern, D.W. (2007) Applied Multivariate Statistical Analysis. 6th ed. Pearson Prentice Hall.

STAT-H-CC10-5-Th **3 Credits**

(Statistical Inference III) **THEORY**

Limit laws (Only statements and applications): Sequence of random variables, convergence in probability, convergence in mean square and convergence in distribution and their interrelations, Weak law of large numbers, Slutsky's Theorem, De-Moivre Laplace Limit theorem, Central Limit Theorem (C.L.T.) for i.i.d. variates. (7)

Large Sample Theory: Delta method, Derivation of large sample standard error of sample moments, standard deviation, coefficient of variation, b_1 and b_2 measures, correlation coefficient and their uses in large sample tests under normality assumption.
Large sample distribution of sample quantiles.

Transformations of Statistics to stabilize variance: derivation and uses of Sin^{-1}, square root, logarithmic and z-transformations.
Large sample tests for binomial proportions, Poisson means (single and two independent samples cases) and correlation coefficients.
Large Sample distribution of Pearsonian χ^2- statistic.
Consistency and Asymptotic Efficiency of Estimators, CAN and BAN estimators, Large sample properties of maximum likelihood estimates and their uses: Likelihood Ratio test, Wald's test and Rao's Score Test. (20)

Nonparametric Tests: Introduction and Concept, Test for randomness based on total number of runs, Empirical distribution function, One Sample Tests: Kolmogrov- Smirnov, Sign, Signed rank. Two-Sample Tests: Wilcoxon rank sum and Wilcoxon-Mann-Whitney test. Multi-sample test: Kruskal-Wallis test. (12)

Sequential Probability Ratio Tests: Introduction, Wald's formulation of SPRT, Operating Characteristic Function, Average Sample Number. (6)

STAT-H-CC10-5-P **1 Credit**

(Statistical Inference III) **PRACTICAL**

List of Suggested Practical

- Test of significance and confidence intervals for single proportion and difference of two proportions using CLT.
- Test of significance and confidence intervals for single Poisson mean and difference of two Poisson means using CLT.
- Test of significance and confidence intervals concerning sample standard deviation, coefficient of variation and correlation coefficient (both single sample and two sample cases).
- Test of significance and confidence intervals using variance stabilizing transformations.
- Test for randomness based on total number of runs.
- Kolmogrov Smirnov test for one sample.
- Sign test.
- Wilcoxon-Mann-Whitney U-test.
- Kruskal-Wallis test.
- SPRT and approximate calculations of OC and ASN functions.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2013): Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B. (2016): An Outline of Statistical Theory, Vol-1. World Press.
- Ferguson, Thomas S. (1996). A Course in Large Sample Theory, 1st Edition. Chapman & Hall.
- Serfling R.J. (1980): Approximation Theory of Mathematical Statistics, John Wiley.
- Chandra T.K. (1999): A First Course in Asymptotic Theory in Statistics, Narosa.
- Rohatgi, V. K. and Saleh, A.K. Md. E. (2009): An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Mood, A.M., Graybill, F.A. and Boes, D.C. (2017): Introduction to the Theory of Statistics, 3rd Edn. (Reprint). Tata McGraw-Hill.
- Hogg, R.V., McKean, J.W. and Craig, A.T. (2021): Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Gibbons, J.D. and Chakraborti, S. (2003): Nonparametric Statistical Inference. 4th ed. Marcel Dekker.

STAT-H-CC11-5-Th **3 Credits**

(Linear Models) **THEORY**

Gauss-Markov set-up: General linear model, General linear hypothesis, Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance. Fundamental Theorems on least squares (statements only), Orthogonal splitting of total variation, selection of valid error. (10)

Analysis of variance: Fixed, random and mixed effect models. Analysis of variance in one-way balanced random effect model. Two-way classified data with equal number of observations per cell for random and mixed effect models. Inference on variance components. (10)

Regression analysis: Simple Linear regression, Multiple Linear Regression. Estimation and hypothesis testing in case of simple and multiple regression models. (15)

Analysis of covariance: Analysis of covariance (with one concomitant variable) in one-way and two-way classified data with equal number of observations per cell. (10)

STAT-H-CC11-5-P **1 Credit**

(Linear Models) **PRACTICAL**

List of Suggested Practical

- Analysis of Variance of a one-way classified data (random effects model).
- Analysis of Variance of a two-way classified data with equal number of observations per cell (random effects model).
- Analysis of Variance of a two-way classified data with equal number of observations per cell (mixed effects model).
- Problems on testing of hypotheses relating to simple linear regression.
- Problems on testing of hypotheses relating to multiple linear regression.
- Analysis of covariance (with one concomitant variable) in one-way classified.
- Analysis of covariance (with one concomitant variable) in two-way classified data with equal number of observations per cell.

Reference Books:

- Goon A.M., Gupta M.K.: Das Gupta. B.: An Outline of Statistical Theory, Vol. II, World Press, Calcutta.
- Weisberg, S. (2005): Applied Linear Regression (Third edition). Wiley.
- Wu, C. F. J. And Hamada, M. (2009): Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
- Renchner, A. C. And Schaalje, G. B. (2008): Linear Models in Statistics (Second edition), John Wiley and Sons.
- Scheffe, H. (1959): The Analysis of Variance, John Wiley.
- Chatterjee S., Hadi A.S., Price B.: Regression Analysis by Example, 3rd Edn, John Wiley & Sons.

STAT-H-CC12-5-Th **3 Credits**

(Demography, Index Numbers and Psychometry) **THEORY**

Demography:

Basic Concepts: Definition and scope of demography. Measurement of population: rates and ratios. (2)

Measures of Mortality and Fertility: Crude Death Rate (CDR), Age-Specific Death Rate (ASDR), Standardized Mortality rate (SMR), Infant Mortality Rate (IMR). Crude Birth Rate (CBR), Age-Specific Fertility Rate (ASFR), General Fertility Rate (GFR), Total Fertility Rate (TFR).

Reproduction Rates: Gross Reproduction Rate (GRR), Net Reproduction Rate (NRR). (6)

Life Tables: Description and uses of life table functions: $l_x, d_x, q_x, L_x, T_x, e_x$. Construction of a life table. (4)

Measures of Population Change: Measurement of population growth: Arithmetic, Geometric, Exponential. Population projection: Concept of stable and stationary population. (3)

Index Numbers:

Introduction to Index Numbers: Meaning and uses of index numbers. Price, quantity, and value index numbers. Simple and weighted index numbers. Errors in index numbers. (4)

Methods of Construction: Laspeyres', Paasche's, Marshall-Edgeworth, Fisher's Ideal, and Kelly's methods. Cost of Living Index (Consumer Price Index), Wholesale Price Index. Time Reversal and Factor Reversal Tests. (9)

Chain Base and Fixed Base Index: Link relative method. Chain index and fixed base index. Base Shifting and Deflating: Base shifting of index numbers. Deflating economic series. (2)

Psychometry:

Basics of Psychometry: Concept of psychological and educational measurement. Attributes: Qualitative vs Quantitative. Scales of measurement: Nominal, Ordinal, Interval, Ratio. (2)

Different types of scaling: Z-scale, T-scale, Percentile-Scale, Equivalent Scale. (3)

Test Construction: Characteristics of a good test: Validity, Reliability, Objectivity, Usability. Methods of reliability estimation: Test-retest, Parallel forms, Split-half, Kuder-Richardson method, Cronbach's alpha. Types of validity: Content, Construct, Criterion-related. (7)

Attitude and Personality Measurement: Likert scale, Thurstone scale. Intelligence and aptitude testing. (3)

STAT-H-CC12-5-P **1 Credit**

(Demography, Index Numbers and Psychometry) **PRACTICAL**

List of Suggested Practical

- Calculate Crude Birth Rate (CBR), General Fertility Rate (GFR), and Age-Specific Fertility Rate (ASFR) using given population and birth data.
- Compute Crude Death Rate (CDR), Infant Mortality Rate (IMR), and Age-Specific Death Rate (ASDR) from a tabulated dataset.
- Construct an abridged life table from given mortality data - calculate $l_x, d_x, q_x, L_x, T_x, e_x$.
- Compute Arithmetic, Geometric, and Exponential growth rates of population using data from two or more time points.
- Construct Price Index Numbers using Laspeyres', Paasche's, and Fisher's Ideal formulae from given price and quantity data.
- Verify Time Reversal and Factor Reversal Tests for Fisher's Index using the above calculation.
- Compute Cost of Living Index from household data.
- Construct Fixed Base and Chain Base Index Numbers.
- Perform Base Shifting and Deflation on a given price index series and interpret results.
- Calculate reliability using the Split-Half Method from a given dataset.
- Compute the Difficulty Index and Discrimination Index for a set of objective test items with student responses.
- Given the inter-item correlations, compute Cronbach's alpha for internal consistency estimation (small dataset).

Reference Books:

- Bhende, A. A. & Kanitkar, T. (2010): Principles of population studies (22nd ed.). Himalaya Publishing House.
- Pathak, K. B. & Ram, F. (1998): Techniques of demographic analysis. Himalaya Publishing House.
- Bogue, D. J. (1969): Principles of demography. John Wiley & Sons.
- Rowland, D. T. (2003): Demographic methods and concepts. Oxford University Press.
- Goon, A. M., Gupta, M. K. & Dasgupta, B. (1986): Fundamentals of statistics (Vol. 2) (6th ed.). World Press.
- Gupta, S. C. & Kapoor, V. K. (2014): Fundamentals of applied statistics (4th ed.). Sultan Chand & Sons.
- Spiegel, M. R., Schiller, J. & Srinivasan, R. A. (2017): Schaum's outline of statistics (5th ed.). McGraw- Hill Education.
- Kendall, M. G. & Stuart, A. (1977): The advanced theory of statistics (Vol. 1) (4th ed.). Charles Griffin & Company.
- Guilford, J. P. (1954): Psychometric methods (2nd ed.). McGraw-Hill.
- Nunnally, J. C. & Bernstein, I. H. (1994): Psychometric theory (3rd ed.). McGraw-Hill.
- Anastasi, A. & Urbina, S. (1997): Psychological testing (7th ed.). Prentice Hall.
- Kline, P. (2000): The handbook of psychological testing (2nd ed.). Routledge.
- Singh, A. K. (2016): Tests, measurements and research methods in behavioural sciences (6th ed.). Bharati Bhawan.

STATISTICS MINOR

STAT-H-MC3-5-Th **3 Credits**

(Statistical Inference I) **THEORY**

Basic concepts of Statistical Inference: population & sample, parameter & statistic, population distribution and sampling distribution. Point estimation, interval estimation and testing of hypothesis. Three useful distributions for statistical Inference: χ^2, t and F (derivations excluded). (5)

Point Estimation: Concepts of estimation, requirements of a good estimator, notions of mean square error, unbiasedness, bias-variance trade off, best linear unbiasedness and minimum variance unbiasedness. Properties of uniformly minimum variance unbiased estimators (UMVUE). Comparison of Estimators, Efficiency. Methods of Estimation: Method of moments, method of maximum likelihood estimation and statements of their small sample properties. Point estimators of the parameters of Binomial, Poisson, and univariate Normal distributions. (15)

Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, p-value. Exact tests and confidence intervals: classical and p-value approaches. Tests relating to Binomial and Poisson distributions, Fisher's exact test. Chi-square tests for association, homogeneity and goodness of fit. Tests of hypotheses for the parameters of normal distribution (one sample and two sample problems), paired t-test. Combination of probabilities in tests of significance. (20)

Interval Estimation: Confidence Interval and Confidence Coefficient, Exact confidence interval for mean(s) and variance(s) for one and two sample problems under the Normal set-up. (5)

STAT-H-MC3-5-P **1 Credit**

(Statistical Inference I) **PRACTICAL**

List of Suggested Practical

- Maximum Likelihood Estimation.
- Estimation by the method of moments.
- Test of significance for single proportion and difference of two proportions.
- Test of significance for single Poisson mean and difference of two Poisson means.
- Chi square tests for association, homogeneity and goodness of fit.
- Test of significance and confidence intervals for single mean and difference of two means.
- Test of significance and confidence intervals for single variance and ratio of two variances.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory, Vol-1. World Press.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Hogg, R.V., Tanis, E.A. and Zimmerman, D. L.: Probability and Statistical Inference. Pearson Education.
- Johnson, R.A. and Bhattacharya, G.K.: Statistics-Principles and Methods, 4th Edn. John Wiley and Sons.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint). Tata McGraw-Hill.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Gupta, S.C. and Kapoor, V.K. (2020): Fundamentals of Mathematical Statistics. Sultan Chand and Sons.
- Ramachandran, K.M. and Tsokos, C.P.: Mathematical Statistics with Applications. Academic Press.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STAT-H-MC4-5-Th **3 Credits**

(Design of Experiments I and Sample Survey I) **THEORY**

Design of Experiments I:

Analysis of Variance: Factors, types and effects; Fixed, random and mixed effects models; Analysis of one-way and two-way classified data with equal number of observations in each cell (Fixed Effects Models only). (10)

Experimental designs: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments (Fisher). (2)

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model, Applications of the techniques of ANOVA to the analysis of the above designs. Missing plot techniques in RBD and LSD. Uniformity trial experiments and comparison of designs. (10)

Sample Survey I:

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, random numbers, procedure of selecting a sample, estimates of population mean, total and proportion, standard errors of these estimates, estimates of their standard errors. (15)

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. (4)

Two-stage sampling (with primary units of equal size and equal selection probability at each stage): unbiased estimation of population mean and total. Ideas of snowball sampling, purposive sampling. (4)

STAT-H-MC4-5-P **1 Credit**

(Design of Experiments I and Sample Survey I) **PRACTICAL**

List of Suggested Practical

- Analysis of Variance of a one-way classified data (fixed effects model).
- Analysis of Variance of a two-way classified data with one observation per cell (fixed effects model).
- Analysis of Variance of a two-way classified data with more than one observation per cell (fixed effects model).
- Analysis of a CRD.
- Analysis of an RBD.
- Analysis of an LSD.
- Analysis of an RBD with one missing observation.
- Analysis of an LSD with one missing observation.
- To select a simple random sample with and without replacement.
- Simple random sampling – estimation of population mean, total and proportion; estimation of related standard error.
- Estimate the sample size for SRSWOR.
- Stratified Sampling –estimation of population mean and total, allocation of sample to strata by proportional and Neyman's methods, Comparison of the efficiencies of the above two methods relative to SRS.
- Estimation of gain in precision in stratified sampling.
- Two-stage Sampling – estimation of population mean and total.

Reference Books:

- Renchner, A. C. And Schaalje, G. B.: Linear Models in Statistics (Second edition), John Wiley and Sons.
- Scheffe, H.: The Analysis of Variance, John Wiley.
- Cochran, W.G. and Cox, G.M.: Experimental Design. Asia Publishing House.
- Das, M.N. and Giri, N.C.: Design and Analysis of Experiments. Wiley Eastern Ltd.
- Kempthorne, O.: The Design and Analysis of Experiments. John Wiley.
- Montgomery, D. C.: Design and Analysis of Experiments, John Wiley.
- Wu, C. F. J. And Hamada, M.: Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
- Dean, A.M. and Voss, D.: Design and Analysis of Experiments. Springer Texts in Statistics.
- Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory, Vol-II, World Press, Calcutta.
- Goon A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol-II, World Press.
- Cochran, W.G.: Sampling Techniques (3rd Ed.), Wiley Eastern.
- Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok, C.: Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Murthy, M.N.: Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P.: Sample Survey Theory, Narosa Publishing House.

SEMESTER - VI

STATISTICS MAJOR

STAT-H-CC13-6-Th **3 Credits**

(Applied Multivariate Analysis) **THEORY**

Types of multivariate techniques: Dependence vs. interdependence methods. (2)

Principal Component Analysis (PCA): Objectives and geometrical interpretation. Computation of principal components. Standardization and correlation matrix-based PCA. Scree plot, proportion of variance explained. Applications and interpretation. Dimensionality reduction and visualization. (13)

Factor Analysis (FA): Basic model: common and unique factors. Estimation of factor loadings (Principal Component Method). Varimax Rotation method (concept only). Factor scores and interpretation. Applications and limitations. (10)

Cluster Analysis: Similarity and dissimilarity measures. Distances: Euclidean, Manhattan, Mahalanobis (conceptual). Hierarchical clustering: single-linkage, complete- linkage, average-linkage. Dendrogram and its interpretation. Non-hierarchical clustering: k-means algorithm. Choosing the number of clusters. Applications in market segmentation, social sciences, etc. (12)

Discriminant Analysis: Problem of classification. Fisher's linear discriminant function. Assumptions and classification rule. Classification with two groups. Cost of misclassification. Applications in biology, marketing, etc. (8)

STAT-H-CC13-6-P **1 Credit**

(Applied Multivariate Analysis) **PRACTICAL**

List of Suggested Practical (Using R)

Data Handling for Multivariate Data:

- Reading multivariate datasets from various file formats (e.g., CSV, Excel) into R.
- Visualizing multivariate data using techniques like scatterplot matrices, and correlation heatmaps.

Principal Component Analysis (PCA):

- Performing PCA on a given dataset using both the covariance matrix and the correlation matrix.
- Visualizing the scree plot to determine the number of principal components to retain.
- Interpreting the principal components based on their loadings and the proportion of variance explained.
- Plotting the data on the first few principal components for dimensionality reduction and visualization.

Factor Analysis (FA):

- Applying Factor Analysis to a dataset, focusing on the Principal Component Method for estimation of factor loadings.
- Performing Varimax rotation on the factor loadings.
- Interpreting the rotated factor loadings to identify underlying factors.
- Calculating and interpreting factor scores for each observation.
- Visualizing factor loadings (e.g., loading plots).

Cluster Analysis:

- Computing various distance/dissimilarity matrices between observations (e.g., Euclidean distance, Manhattan distance).
- Performing different hierarchical clustering methods (e.g., single-linkage, complete-linkage, average- linkage) and visualizing the results using dendrograms.
- Interpreting dendrograms to identify potential clusters.
- Applying non-hierarchical clustering algorithms like k-means clustering.
- Methods for choosing the number of clusters (e.g., Elbow method, Silhouette score).
- Visualizing the resulting clusters (e.g., scatter plots with cluster assignments).

Discriminant Analysis:

- Applying Fisher's linear discriminant analysis to a dataset with two known groups.
- Developing a classification rule based on the discriminant function.
- Constructing and interpreting a confusion matrix.
- Calculating and interpreting the misclassification rate and considering the cost of misclassification.
- Visualizing group separation based on the discriminant function.

Reference Books

- Anderson, T. W. (2003): An Introduction To Multivariate Statistical Analysis (3rd ed.). Hoboken, NJ: Wiley.
- Chatfield, C. & Collins, A. J. (1980): Introduction to Multivariate Analysis. London: Chapman and Hall.
- Everitt, B. S. & Hothorn, T. (2011): An Introduction to Applied Multivariate Analysis with R. New York, NY: Springer.
- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019): Multivariate Data Analysis (8th ed.).

STAT-H-CC14-6-Th **3 Credits**

(Regression Analysis) **THEORY**

Gauss Markov Model: Correlated set-up, least squares estimate with restriction on parameters. (3)

Building a regression model: Transformations – Box-Cox models. (7)

Dummy variables, piecewise regression, splines and scatter plot smoothing. (6)

Detection of outliers and influential observations: Residuals and leverages, DFBETA, DFFIT, Cook's Distance. (4)

Regression Diagnostics: Model checking: Prediction from a fitted model. Variable selection (adjusted R^2, Cp criteria, AIC). (12)

Multicollinearity: Detection (condition number and VIF) and remedial measures. (8)

Binary data regression: Logistic Regression (Grouped and ungrouped data). (5)

STAT-H-CC14-6-P **1 Credit**

(Regression Analysis) **PRACTICAL**

List of Suggested Practical

- Problems on transformation
- Problems on using dummy variables
- Problems on outlier detection
- Problems on variable selection
- Problems on multicollinearity – detection and remedial measures
- Problems on fitting logistic regression

Reference Books

- C.R. Rao: Linear Statistical Inference and its Applications.
- R. B. Bapat: Linear Algebra and Linear Model.
- H. Scheffe: The Analysis of Variance.
- S.R. Searle: Linear Models.
- G.A.F. Seber: Linear Regression Analysis.
- N.C. Giri: Analysis of Variance.
- N.R. Draper & H. Smith: Applied Regression Analysis.
- D.W. Belsley, E. Kuh & R.E. Welsch: Regression Diagnostics – identifying Influential data & sources of collinearity.
- J. Rousseeuw & A.M. Leroy: Robust Regression & Outlier Detection.
- R.D. Cook & S. Weisberg: Residual and its Influence in Regression.
- S. Chatterjee & A.S. Hadi: Regression Analysis by Example.
- J. Johnston: Econometric Methods (3rd ed.).
- G.G. Judge, W.E. Griffith, et. al.: The Theory and Practice of Econometrics (2nd ed.).
- T.P. Ryan: Modern Regression Methods (2nd ed.).
- A. Agresti: Analysis of Ordinal Categorical Data.
- A. Agresti: Categorical Data Analysis.

STAT-H-CC15-6-Th **3 Credits**

(Time Series Analysis) **THEORY**

Introduction to Time Series: Definition and applications of time series. Objectives of time series analysis. Stationary and evolutionary processes. Trend and Seasonality. Additive and multiplicative models. Graphical representation of time series data. (5)

Trend Analysis: Deterministic trend models: linear, quadratic, exponential. Estimation of trend using: Moving averages (Simple, Centered), Least squares method. Deseasonalization. (8)

Seasonal and Cyclical Components: Seasonal variation: Identification. Methods of seasonal adjustment: Ratio to moving average method, Ratio to trend method, Link relative method. Concept of cyclical variation and its distinction from seasonality. (9)

Stationarity and Autocorrelation: Concept of stationarity. Autocorrelation function (ACF) and partial auto-correlation function (PACF). White noise and random walk models. (8)

Time Series Models: AR (Auto-Regressive), MA (Moving Average), ARMA, and ARIMA Models. Forecasting. Test of randomness: Pormanteau and Ljung-Box. Concept of model selection (AIC: brief idea). (15)

STAT-H-CC15-6-P **1 Credit**

(Time Series Analysis) **PRACTICAL**

List of Suggested Practical

- Graphical Representation and Component Identification: Plotting given time series data and identifying trend, seasonal, and irregular components.
- Fitting Deterministic Trend Models: Fit a linear trend model to time series data using the least squares method. Fit a quadratic trend model using least squares method. Fit an exponential trend model by transforming data logarithmically and applying least squares.
- Estimation of Trend Using Moving Averages: Compute simple moving average (odd and even periods). Apply centered moving average to smooth data. Extract trend values and interpret the result.
- Deseasonalization: Remove seasonality from given data using seasonal indices.
- Estimation of Seasonal Indices: Compute seasonal indices using: Ratio to Moving Average method, Ratio to Trend method, Link Relative method.
- Calculation and Plotting of ACF and PACF: Compute the autocorrelation coefficients up to lag 5 or 10 (using formula). Plot ACF and PACF and interpret lag behavior (e.g., identify AR or MA process nature).
- Forecasting Using Fitted ARIMA Models: Given AR model parameters, compute one-step ahead or two-step ahead forecasts. Compute forecasts using a fitted ARIMA(1,0,0) or ARIMA(0,1,1) model.

Reference Books:

- Box, G. E. P., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015): Time series analysis: Forecasting and control (5th ed.). Hoboken, NJ: Wiley.
- Chatfield, C. (2004): The analysis of time series: An introduction (6th ed.). Boca Raton, FL: Chapman & Hall/CRC.
- Anderson, T. W. (1971): The statistical analysis of time series. New York, NY: Wiley.
- Kendall, M. G., & Ord, J. K. (1990): Time series (3rd ed.). London, UK: Edward Arnold.
- Shumway, R. H., & Stoffer, D. S. (2017): Time series analysis and its applications: With R examples (4th ed.). Cham, Switzerland: Springer.

STATISTICS MINOR

STAT-H-MC3-6-Th **3 Credits**

(Statistical Inference I) **THEORY**

Basic concepts of Statistical Inference: population & sample, parameter & statistic, population distribution and sampling distribution. Point estimation, interval estimation and testing of hypothesis. Three useful distributions for statistical Inference: χ^2, t and F (derivations excluded). (5)

Point Estimation: Concepts of estimation, requirements of a good estimator, notions of mean square error, unbiasedness, bias-variance trade off, best linear unbiasedness and minimum variance unbiasedness. Properties of uniformly minimum variance unbiased estimators (UMVUE). Comparison of Estimators, Efficiency. Methods of Estimation: Method of moments, method of maximum likelihood estimation and statements of their small sample properties. Point estimators of the parameters of Binomial, Poisson, and univariate Normal distributions. (15)

Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, p-value. Exact tests and confidence intervals: classical and p-value approaches. Tests relating to Binomial and Poisson distributions, Fisher's exact test. Chi-square tests for association, homogeneity and goodness of fit. Tests of hypotheses for the parameters of normal distribution (one sample and two sample problems), paired t-test. Combination of probabilities in tests of significance. (20)

Interval Estimation: Confidence Interval and Confidence Coefficient, Exact confidence interval for mean(s) and variance(s) for one and two sample problems under the Normal set-up. (5)

STAT-H-MC3-6-P **1 Credit**

(Statistical Inference I) **PRACTICAL**

List of Suggested Practical

- Maximum Likelihood Estimation.
- Estimation by the method of moments.
- Test of significance for single proportion and difference of two proportions.
- Test of significance for single Poisson mean and difference of two Poisson means.
- Chi square tests for association, homogeneity and goodness of fit.
- Test of significance and confidence intervals for single mean and difference of two means.
- Test of significance and confidence intervals for single variance and ratio of two variances.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory, Vol-1. World Press.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Hogg, R.V., Tanis, E.A. and Zimmerman, D. L.: Probability and Statistical Inference. Pearson Education.
- Johnson, R.A. and Bhattacharya, G.K.: Statistics-Principles and Methods, 4th Edn. John Wiley and Sons.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint). Tata McGraw-Hill.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Gupta, S.C. and Kapoor, V.K. (2020): Fundamentals of Mathematical Statistics. Sultan Chand and Sons.
- Ramachandran, K.M. and Tsokos, C.P.: Mathematical Statistics with Applications. Academic Press.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STAT-H-MC4-6-Th **3 Credits**

(Design of Experiments I and Sample Survey I) **THEORY**

Design of Experiments I:

Analysis of Variance: Factors, types and effects; Fixed, random and mixed effects models; Analysis of one-way and two-way classified data with equal number of observations in each cell (Fixed Effects Models only). (10)

Experimental designs: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments (Fisher). (2)

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model, Applications of the techniques of ANOVA to the analysis of the above designs. Missing plot techniques in RBD and LSD. Uniformity trial experiments and comparison of designs. (10)

Sample Survey I:

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, random numbers, procedure of selecting a sample, estimates of population mean, total and proportion, standard errors of these estimates, estimates of their standard errors. (15)

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. (4)

Two-stage sampling (with primary units of equal size and equal selection probability at each stage): unbiased estimation of population mean and total. Ideas of snowball sampling, purposive sampling. (4)

STAT-H-MC4-6-P **1 Credit**

(Design of Experiments I and Sample Survey I) **PRACTICAL**

List of Suggested Practical

- Analysis of Variance of a one-way classified data (fixed effects model).
- Analysis of Variance of a two-way classified data with one observation per cell (fixed effects model).
- Analysis of Variance of a two-way classified data with more than one observation per cell (fixed effects model).
- Analysis of a CRD.
- Analysis of an RBD.
- Analysis of an LSD.
- Analysis of an RBD with one missing observation.
- Analysis of an LSD with one missing observation.
- To select a simple random sample with and without replacement.
- Simple random sampling – estimation of population mean, total and proportion; estimation of related standard error.
- Estimate the sample size for SRSWOR.
- Stratified Sampling –estimation of population mean and total, allocation of sample to strata by proportional and Neyman's methods, Comparison of the efficiencies of the above two methods relative to SRS.
- Estimation of gain in precision in stratified sampling.
- Two-stage Sampling – estimation of population mean and total.

Reference Books:

- Renchner, A. C. And Schaalje, G. B.: Linear Models in Statistics (Second edition), John Wiley and Sons.
- Scheffe, H.: The Analysis of Variance, John Wiley.
- Cochran, W.G. and Cox, G.M.: Experimental Design. Asia Publishing House.
- Das, M.N. and Giri, N.C.: Design and Analysis of Experiments. Wiley Eastern Ltd.
- Kempthorne, O.: The Design and Analysis of Experiments. John Wiley.
- Montgomery, D. C.: Design and Analysis of Experiments, John Wiley.
- Wu, C. F. J. And Hamada, M.: Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
- Dean, A.M. and Voss, D.: Design and Analysis of Experiments. Springer Texts in Statistics.
- Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory, Vol-II, World Press, Calcutta.
- Goon A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol-II, World Press.
- Cochran, W.G.: Sampling Techniques (3rd Ed.), Wiley Eastern.
- Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok, C.: Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Murthy, M.N.: Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P.: Sample Survey Theory, Narosa Publishing House.

UNIVERSITY OF CALCUTTA

Syllabus

for

Three-year B.Sc. Multidisciplinary Courses of Studies

in

STATISTICS

(Under Curriculum & Credit Framework, 2022)

[Semesters I, II, III, IV, V and VI]

With effect from the Academic Session

2023-24

Structure of Core Courses in Statistics for MDC

Semester	Course / Paper Code	Course Name
I	STAT-MD-CC1-1-Th / P	Descriptive Statistics I & Probability I
II	STAT-MD-CC2-2-Th / P	Descriptive Statistics II & Probability II
III	STAT-MD-CC3-3-Th / P	Statistical Inference I
IV	STAT-MD-CC4-4-Th / P	Design of Experiments I and Sample Survey I
	STAT-MD-CC5-4-Th / P	Descriptive Statistics III & Probability III
V	STAT-MD-CC6-5-P	Project Work
V OR VI	STAT-MD-CC7-5-Th / P OR STAT-MD-CC7-6-Th / P	Applications of Statistics I
VI	STAT-MD-CC8-6-Th / P	Applications of Statistics II

Structure of Minor Courses in Statistics for MDC

Semester	Course / Paper Code	Course Name
III	STAT-MD-MC1-3-Th / P	Descriptive Statistics I & Probability I
IV	STAT-MD-MC2-4-Th / P	Descriptive Statistics II & Probability II
V	STAT-MD-MC3-5-Th / P	Statistical Inference I
	STAT-MD-MC4-5-P	Project Work
VI	STAT-MD-MC5-6-Th / P	Design of Experiments I and Sample Survey I
	STAT-MD-MC6-6-Th / P	Descriptive Statistics III & Probability III

Structure of Skill Enhancement Courses in Statistics for MDC

Semester	Course / Paper Code	Course Name
I	STAT-MD-SEC1-1-Th / TU	An Introduction to R
II	STAT-MD-SEC2-2-Th / TU	
III	STAT-MD-SEC3-3-Th / TU	

Structure of Interdisciplinary Courses in Statistics for MDC

Semester	Course / Paper Code	Course Name
I	STAT-MD-IDC1-1-Th / P	Statistics for Practitioners
II	STAT-MD-IDC2-2-Th / P	
III	STAT-MD-IDC3-3-Th / P	

Question Patterns

SEMESTER - I

STATISTICS MAJOR

STAT-MD-CC1-1-Th **3 Credits**

(Descriptive Statistics I & Probability I) **THEORY**

Statistics: Definition and scope. Concepts of statistical population and sample.

Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous.

Scales of measurement: nominal, ordinal, interval and ratio.

Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays. (10)

Measures of Central Tendency: Mean, Median, Mode.

Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation, Ginis Coefficient, Lorenz Curve. Moments, skewness and kurtosis. Quantiles and measures based on them. Box Plot. Outliers. (15)

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability: classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (20)

STAT-MD-CC1-1-P **1 Credit**

(Descriptive Statistics I & Probability I) **PRACTICAL**

List of Suggested Practical

- Diagrammatic representation of data.
- Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations, stem and leaf plot.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation.
- Problems based on moments, skewness and kurtosis.
- Problems related to quantiles and measures based on them, construction of box plot.
- Application problems based on Classical Definition of Probability.
- Application problems based on Bayes' Theorem.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Gupta, S.C., Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons

STAT-MD-SEC1-1-Th **3 Credits**

(An Introduction to R) **THEORY**

Introduction to R: Installation, command line environment, overview of capabilities, brief mention of open source philosophy.

R as a calculator: The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers. Standard functions, e.g., sin, cos, exp, log. (10)

The different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. (No need to go into details). Variables. Creating a vector using c(), seq() and colon operator. How functions map over vectors. Functions to summarise a vector: sum, mean, sd, median etc. Extracting a subset from the vector (by index, by property).

R as a graphing calculator: Introduction to plotting. Plot(), lines(), abline(). No details about the graphics parameters except colour and line width. Barplot, Pie chart and Histogram. Box plot. (15)

Matrix operations in R: Creation. Basic operations. Extracting submatrices.

Loading data from a file: read.table() and read.csv(). Mention of head=TRUE and head=FALSE. Dataframes. Mention that these are like matrices, except that different columns may be of different types. (8)

Numerical Integration in R: Trapezoidal and Simpson's 1/3-rd rules.

Numerical solution of equations in R: Method of fixed-point iteration and Newton-Raphson method in one unknown.

Simulation in R: Simulating a coin toss, a die roll and a card shuffle. Finding probabilities of events related to such experiments using simulation. (12)

STAT-MD-SEC1-1-TU **1 Credit**

(An Introduction to R) **TUTORIAL**

Reference Books:

- Gardener, M.: Beginning R - The Statistical Programming Language, Wiley Publications.
- Braun W J, Murdoch D J: A First Course in Statistical Programming with R. Cambridge University Press. New York.
- A simple introduction to R by Arnab Chakraborty
  (freely available at http://www.isical.ac.in/~arnabc/)
- R for beginners by Emmanuel Paradis
  (freely available at https://cran.r-project.org/doc/contrib/Paradisrdebuts_en.pdf)

STATISTICS INTERDISCIPLINARY

STAT-MD-IDC1-1-Th **2 Credits**

(Statistics for Practitioners) **THEORY**

Understanding univariate data: Variable, notion of population and sample, different types of data, methods of collecting primary and secondary data, presentation of data, summary measures on data with central tendency (arithmetic mean, median, mode), dispersion (range, quartile deviation, standard deviation, coefficient of variation), ideas of skewness and kurtosis (only through diagrams), Exploratory Data Analysis. (8)

Understanding bivariate data: Paired data and ideas (without mathematical details) of different measures of associations, primarily Pearson's correlation coefficient, Spearman's Rank correlation (no tie), measures of association of attributes through contingency table, two-variable linear regression and multiple (three-variable only) linear regression (without derivation of the regression coefficients' formulae). (8)

Statistical Inference (*testing of hypothesis*): Basic idea of binomial and normal populations (graphical idea only, derivation of the properties excluded). Concepts of hypotheses, knowledge on test statistic and decision making in terms of critical value and p-value for some standard testing problems like test for proportion/proportions, mean based on single (normal) sample, test on comparing means based on two-sample and paired sample data. (7)

Miscellaneous discussion: Applications of one-way and two-way ANOVA with one observation per cell (without derivation and details) assuming normality, Kruskal-Wallis test (without derivation and details), sample size determination, estimation of population mean and variability for finite population, idea and application of logistic regression for binary response data. (7)

STAT-MD-IDC1-1-P **1 Credit**

(Statistics for Practitioners) **PRACTICAL**

List of Suggested Practical

- Measures of mean, median, mode, range, QD, SD, CV for univariate data case.
- Fitting of linear regression on bivariate and on three-variable multivariate data, measures of Pearson's correlation coefficient, Spearman's Rank correlation, measures of association of attributes through contingency table.
- Tests for proportion/proportions, tests of means for single sample, two-sample, and paired sample data on normal response using p-value approach.
- Applications of ANOVA and Kruskal-Wallis test.
- Sample size determination, estimation of population mean and variability for finite population.
- Fitting of logistic regression for binary response data.

Reference Books:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata.
- Das, N.G.: Statistical Methods, Vol I, Tata McGraw Hill Pub. Co. Ltd.
- Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis, PHI.
- Hardle W. and Simar, L.: Applied Multivariate Statistical Analysis.
- Kutner, M.H. et.al.: Applied Linear Statistical Models.
- Belsley D.A. et.al.: Regression Diagnostics.
- Draper N.R. and Smith, H.: Applied Regression Analysis.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

SEMESTER - II

STATISTICS MAJOR

STAT-MD-CC2-2-Th **3 Credits**

(Descriptive Statistics II & Probability II) **THEORY**

Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intraclass correlation.

Rank correlation: Spearman's and Kendall's measures. (15)

Analysis of Categorical Data: Contingency table, independence & association of attributes. (5)

Random Variables: Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (without proof), probability mass function (p.m.f.) and probability density function (p.d.f.). Expectation and Variance. Standard probability distributions: Discrete Uniform, Binomial, Poisson, and Normal. (25)

STAT-MD-CC2-2-P **1 Credit**

(Descriptive Statistics II & Probability II) **PRACTICAL**

List of Suggested Practical

- Problems based on analysis of bivariate data.
- Problems based on measures of rank correlation.
- Problems based on analysis of categorical data.
- Finding expectation, variance from a given probability distribution.
- Fitting of binomial distributions for n and p = q = 1/2.
- Fitting of binomial distributions for given n and p.
- Fitting of binomial distributions after computing mean and variance.
- Fitting of Poisson distributions for given value of mean.
- Fitting of Poisson distributions after computing mean.
- Application problems based on binomial distribution.
- Application problems based on Poisson distribution.
- Problems based on area property of normal distribution.
- To find the ordinate for a given area for normal distribution.

- Application based problems using normal distribution.
- Fitting of normal distribution when parameters are given.
- Fitting of normal distribution when parameters are not given.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, (7^{th} Edn.), Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3^{rd} Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Agresti, A.: Analysis of Ordinal Categorical Data, 2^{nd} Edition, Wiley.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, 4^{th} Edition, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Hogg, R.V., Tanis, E.A. and Rao J.M.: Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
- Myer, P.L.: Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2^{nd} Edn. (Reprint) John Wiley and Sons.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Gupta, S.C., Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons

STAT-MD-SEC2-2-Th **3 Credits**

(An Introduction to R) **THEORY**

Introduction to R: Installation, command line environment, overview of capabilities, brief mention of open source philosophy.

R as a calculator: The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers. Standard functions, e.g., sin, cos, exp, log. (10)

The different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. (No need to go into details). Variables. Creating a vector using c(), seq() and colon operator. How functions map over vectors. Functions to summarise a vector: sum, mean, sd, median etc. Extracting a subset from the vector (by index, by property).

R as a graphing calculator: Introduction to plotting. Plot(), lines(), abline(). No details about the graphics parameters except colour and line width. Barplot, Pie chart and Histogram. Box plot. (15)

Matrix operations in R: Creation. Basic operations. Extracting submatrices.

Loading data from a file: read.table() and read.csv(). Mention of head=TRUE and head=FALSE. Dataframes. Mention that these are like matrices, except that different columns may be of different types. (8)

Numerical Integration in R: Trapezoidal and Simpson's 1/3-rd rules.

Numerical solution of equations in R: Method of fixed-point iteration and Newton-Raphson method in one unknown.

Simulation in R: Simulating a coin toss, a die roll and a card shuffle. Finding probabilities of events related to such experiments using simulation. (12)

STAT-MD-SEC2-2-TU **1 Credit**

(An Introduction to R) **TUTORIAL**

Reference Books:

- Gardener, M.: Beginning R - The Statistical Programming Language, Wiley Publications.
- Braun W J, Murdoch D J: A First Course in Statistical Programming with R. Cambridge University Press. New York.
- A simple introduction to R by Arnab Chakraborty
  (freely available at http://www.isical.ac.in/~arnabc/)
- R for beginners by Emmanuel Paradis
  (freely available at https://cran.r-project.org/doc/contrib/Paradisrdebuts_en.pdf)

STATISTICS INTERDISCIPLINARY

STAT-MD-IDC2-2-Th **2 Credits**

(Statistics for Practitioners) **THEORY**

Understanding univariate data: Variable, notion of population and sample, different types of data, methods of collecting primary and secondary data, presentation of data, summary measures on data with central tendency (arithmetic mean, median, mode), dispersion (range, quartile deviation, standard deviation, coefficient of variation), ideas of skewness and kurtosis (only through diagrams), Exploratory Data Analysis. (8)

Understanding bivariate data: Paired data and ideas (without mathematical details) of different measures of associations, primarily Pearson's correlation coefficient, Spearman's Rank correlation (no tie), measures of association of attributes through contingency table, two-variable linear regression and multiple (three-variable only) linear regression (without derivation of the regression coefficients' formulae). (8)

Statistical Inference (*testing of hypothesis*): Basic idea of binomial and normal populations (graphical idea only, derivation of the properties excluded). Concepts of hypotheses, knowledge on test statistic and decision making in terms of critical value and p-value for some standard testing problems like test for proportion/proportions, mean based on single (normal) sample, test on comparing means based on two-sample and paired sample data. (7)

Miscellaneous discussion: Applications of one-way and two-way ANOVA with one observation per cell (without derivation and details) assuming normality, Kruskal-Wallis test (without derivation and details), sample size determination, estimation of population mean and variability for finite population, idea and application of logistic regression for binary response data. (7)

STAT-MD-IDC2-2-P **1 Credit**

(Statistics for Practitioners) **PRACTICAL**

List of Suggested Practical

- Measures of mean, median, mode, range, QD, SD, CV for univariate data case.
- Fitting of linear regression on bivariate and on three-variable multivariate data, measures of Pearson's correlation coefficient, Spearman's Rank correlation, measures of association of attributes through contingency table.
- Tests for proportion/proportions, tests of means for single sample, two-sample, and paired sample data on normal response using p-value approach.
- Applications of ANOVA and Kruskal-Wallis test.
- Sample size determination, estimation of population mean and variability for finite population.
- Fitting of logistic regression for binary response data.

Reference Books:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata.
- Das, N.G.: Statistical Methods, Vol I, Tata McGraw Hill Pub. Co. Ltd.
- Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis, PHI.
- Hardle W. and Simar, L.: Applied Multivariate Statistical Analysis.
- Kutner, M.H. et.al.: Applied Linear Statistical Models.
- Belsley D.A. et.al.: Regression Diagnostics.
- Draper N.R. and Smith, H.: Applied Regression Analysis.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

SEMESTER - III

STATISTICS MAJOR

STAT-MD-CC3-3-Th **3 Credits**

(Statistical Inference I) **THEORY**

Basic concepts of Statistical Inference: population & sample, parameter & statistic, population distribution and sampling distribution. Point estimation, interval estimation and testing of hypothesis. Three useful distributions for statistical Inference: χ^2, t and F (derivations excluded). (5)

Point Estimation: Concepts of estimation, requirements of a good estimator, notions of mean square error, unbiasedness, bias-variance trade off, best linear unbiasedness and minimum variance unbiasedness. Properties of uniformly minimum variance unbiased estimators (UMVUE). Comparison of Estimators, Efficiency. Methods of Estimation: Method of moments, method of maximum likelihood estimation and statements of their small sample properties. Point estimators of the parameters of Binomial, Poisson, and univariate Normal distributions. (15)

Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, p-value. Exact tests and confidence intervals: classical and p-value approaches. Tests relating to Binomial and Poisson distributions, Fisher's exact test. Chi-square tests for association, homogeneity and goodness of fit. Tests of hypotheses for the parameters of normal distribution (one sample and two sample problems), paired t-test. Combination of probabilities in tests of significance. (20)

Interval Estimation: Confidence Interval and Confidence Coefficient, Exact confidence interval for mean(s) and variance(s) for one and two sample problems under the Normal set-up. (5)

STAT-MD-CC3-3-P **1 Credit**

(Statistical Inference I) **PRACTICAL**

List of Suggested Practical

- Maximum Likelihood Estimation.
- Estimation by the method of moments.
- Test of significance for single proportion and difference of two proportions.
- Test of significance for single Poisson mean and difference of two Poisson means.
- Chi square tests for association, homogeneity and goodness of fit.
- Test of significance and confidence intervals for single mean and difference of two means.
- Test of significance and confidence intervals for single variance and ratio of two variances.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory, Vol-1. World Press.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Hogg, R.V., Tanis, E.A. and Zimmerman, D. L.: Probability and Statistical Inference. Pearson Education.
- Johnson, R.A. and Bhattacharya, G.K.: Statistics-Principles and Methods, 4th Edn. John Wiley and Sons.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint). Tata McGraw-Hill.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Gupta, S.C. and Kapoor, V.K. (2020): Fundamentals of Mathematical Statistics. Sultan Chand and Sons.
- Ramachandran, K.M. and Tsokos, C.P.: Mathematical Statistics with Applications. Academic Press.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STATISTICS MINOR

STAT-MD-MC1-3-Th **3 Credits**

(Descriptive Statistics I & Probability I) **THEORY**

Statistics: Definition and scope. Concepts of statistical population and sample.

Data: quantitative and qualitative, cross-sectional and time-series, discrete and continuous.

Scales of measurement: nominal, ordinal, interval and ratio.

Presentation of data: tabular and graphical. Frequency distributions, cumulative frequency distributions and their graphical representations. Stem and leaf displays. (10)

Measures of Central Tendency: Mean, Median, Mode.

Measures of Dispersion: Range, Mean deviation, Standard deviation, Coefficient of variation, Ginis Coefficient, Lorenz Curve. Moments, skewness and kurtosis. Quantiles and measures based on them. Box Plot. Outliers. (15)

Probability: Introduction, random experiments, sample space, events and algebra of events. Definitions of Probability: classical, statistical, and axiomatic. Conditional Probability, laws of addition and multiplication, independent events, theorem of total probability, Bayes' theorem and its applications. (20)

STAT-MD-MC1-3-P **1 Credit**

(Descriptive Statistics I & Probability I) **PRACTICAL**

List of Suggested Practical

- Diagrammatic representation of data.
- Problems based on construction of frequency distributions, cumulative frequency distributions and their graphical representations, stem and leaf plot.
- Problems based on measures of central tendency.
- Problems based on measures of dispersion.
- Problems based on combined mean and variance and coefficient of variation.
- Problems based on moments, skewness and kurtosis.
- Problems related to quantiles and measures based on them, construction of box plot.
- Application problems based on Classical Definition of Probability.
- Application problems based on Bayes' Theorem.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Gupta, S.C., Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons

STAT-MD-SEC3-3-Th **3 Credits**

(An Introduction to R) **THEORY**

Introduction to R: Installation, command line environment, overview of capabilities, brief mention of open source philosophy.

R as a calculator: The four basic arithmetic operations. Use of parentheses nesting up to arbitrary level. The power operation. Evaluation of simple expressions. Quotient and remainder operations for integers. Standard functions, e.g., sin, cos, exp, log. (10)

The different types of numbers in R: Division by zero leading to Infor -Inf. NaN. NA. (No need to go into details). Variables. Creating a vector using c(), seq() and colon operator. How functions map over vectors. Functions to summarise a vector: sum, mean, sd, median etc. Extracting a subset from the vector (by index, by property).

R as a graphing calculator: Introduction to plotting. Plot(), lines(), abline(). No details about the graphics parameters except colour and line width. Barplot, Pie chart and Histogram. Box plot. (15)

Matrix operations in R: Creation. Basic operations. Extracting submatrices.

Loading data from a file: read.table() and read.csv(). Mention of head=TRUE and head=FALSE. Dataframes. Mention that these are like matrices, except that different columns may be of different types. (8)

Numerical Integration in R: Trapezoidal and Simpson's 1/3-rd rules.

Numerical solution of equations in R: Method of fixed-point iteration and Newton-Raphson method in one unknown.

Simulation in R: Simulating a coin toss, a die roll and a card shuffle. Finding probabilities of events related to such experiments using simulation. (12)

STAT-MD-SEC3-3-TU **1 Credit**

(An Introduction to R) **TUTORIAL**

Reference Books:

- Gardener, M.: Beginning R - The Statistical Programming Language, Wiley Publications.
- Braun W J, Murdoch D J: A First Course in Statistical Programming with R. Cambridge University Press. New York.
- A simple introduction to R by Arnab Chakraborty
  (freely available at http://www.isical.ac.in/~arnabc/)
- R for beginners by Emmanuel Paradis
  (freely available at https://cran.r-project.org/doc/contrib/Paradisrdebuts_en.pdf)

STATISTICS INTERDISCIPLINARY

STAT-MD-IDC3-3-Th **2 Credits**

(Statistics for Practitioners) **THEORY**

Understanding univariate data: Variable, notion of population and sample, different types of data, methods of collecting primary and secondary data, presentation of data, summary measures on data with central tendency (arithmetic mean, median, mode), dispersion (range, quartile deviation, standard deviation, coefficient of variation), ideas of skewness and kurtosis (only through diagrams), Exploratory Data Analysis. (8)

Understanding bivariate data: Paired data and ideas (without mathematical details) of different measures of associations, primarily Pearson's correlation coefficient, Spearman's Rank correlation (no tie), measures of association of attributes through contingency table, two-variable linear regression and multiple (three-variable only) linear regression (without derivation of the regression coefficients' formulae). (8)

Statistical Inference (*testing of hypothesis*): Basic idea of binomial and normal populations (graphical idea only, derivation of the properties excluded). Concepts of hypotheses, knowledge on test statistic and decision making in terms of critical value and p-value for some standard testing problems like test for proportion/proportions, mean based on single (normal) sample, test on comparing means based on two-sample and paired sample data. (7)

Miscellaneous discussion: Applications of one-way and two-way ANOVA with one observation per cell (without derivation and details) assuming normality, Kruskal-Wallis test (without derivation and details), sample size determination, estimation of population mean and variability for finite population, idea and application of logistic regression for binary response data. (7)

STAT-MD-IDC3-3-P **1 Credit**

(Statistics for Practitioners) **PRACTICAL**

List of Suggested Practical

- Measures of mean, median, mode, range, QD, SD, CV for univariate data case.
- Fitting of linear regression on bivariate and on three-variable multivariate data, measures of Pearson's correlation coefficient, Spearman's Rank correlation, measures of association of attributes through contingency table.
- Tests for proportion/proportions, tests of means for single sample, two-sample, and paired sample data on normal response using p-value approach.
- Applications of ANOVA and Kruskal-Wallis test.
- Sample size determination, estimation of population mean and variability for finite population.
- Fitting of logistic regression for binary response data.

Reference Books:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. I, 9th Edition World Press, Kolkata.
- Das, N.G.: Statistical Methods, Vol I, Tata McGraw Hill Pub. Co. Ltd.
- Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis, PHI.
- Hardle W. and Simar, L.: Applied Multivariate Statistical Analysis.
- Kutner, M.H. et.al.: Applied Linear Statistical Models.
- Belsley D.A. et.al.: Regression Diagnostics.
- Draper N.R. and Smith, H.: Applied Regression Analysis.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

SEMESTER - IV

STATISTICS MAJOR

STAT-MD-CC4-4-Th **3 Credits**

(Design of Experiments I and Sample Survey I) **THEORY**

Design of Experiments I:

Analysis of Variance: Factors, types and effects; Fixed, random and mixed effects models; Analysis of one-way and two-way classified data with equal number of observations in each cell (Fixed Effects Models only). (10)

Experimental designs: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments (Fisher). (2)

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model, Applications of the techniques of ANOVA to the analysis of the above designs. Missing plot techniques in RBD and LSD. Uniformity trial experiments and comparison of designs. (10)

Sample Survey I:

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, random numbers, procedure of selecting a sample, estimates of population mean, total and proportion, standard errors of these estimates, estimates of their standard errors. (15)

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. (4)

Two-stage sampling (with primary units of equal size and equal selection probability at each stage): unbiased estimation of population mean and total. Ideas of snowball sampling, purposive sampling. (4)

STAT-MD-CC4-4-P **1 Credit**

(Design of Experiments I and Sample Survey I) **PRACTICAL**

List of Suggested Practical

- Analysis of Variance of a one-way classified data (fixed effects model).
- Analysis of Variance of a two-way classified data with one observation per cell (fixed effects model).
- Analysis of Variance of a two-way classified data with more than one observation per cell (fixed effects model).
- Analysis of a CRD.
- Analysis of an RBD.
- Analysis of an LSD.
- Analysis of an RBD with one missing observation.
- Analysis of an LSD with one missing observation.
- To select a simple random sample with and without replacement.
- Simple random sampling – estimation of population mean, total and proportion; estimation of related standard error.
- Estimate the sample size for SRSWOR.
- Stratified Sampling –estimation of population mean and total, allocation of sample to strata by proportional and Neyman's methods, Comparison of the efficiencies of the above two methods relative to SRS.
- Estimation of gain in precision in stratified sampling.
- Two-stage Sampling – estimation of population mean and total.

Reference Books:

- Renchner, A. C. And Schaalje, G. B.: Linear Models in Statistics (Second edition), John Wiley and Sons.
- Scheffe, H.: The Analysis of Variance, John Wiley.
- Cochran, W.G. and Cox, G.M.: Experimental Design. Asia Publishing House.
- Das, M.N. and Giri, N.C.: Design and Analysis of Experiments. Wiley Eastern Ltd.
- Kempthorne, O.: The Design and Analysis of Experiments. John Wiley.
- Montgomery, D. C.: Design and Analysis of Experiments, John Wiley.

- Wu, C. F. J. And Hamada, M.: Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
- Dean, A.M. and Voss, D.: Design and Analysis of Experiments. Springer Texts in Statistics.
- Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory, Vol-II, World Press, Calcutta.
- Goon A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol-II, World Press.
- Cochran, W.G.: Sampling Techniques (3rd Ed.), Wiley Eastern.
- Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok, C.: Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Murthy, M.N.: Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P.: Sample Survey Theory, Narosa Publishing House.

STAT-MD-CC5-4-Th **3 Credits**

(Descriptive Statistics III and Probability III) **THEORY**

Descriptive Statistics III (15)

Multivariate frequency distribution: multivariate data, multiple regression, multiple correlation, partial correlation coefficient, Particular case with three variates.

Probability III (30)

Moments, Quantiles, Skewness and Kurtosis (including discussions of these measures for Binomial, Poisson and Univariate Normal Distributions). Generating functions – probability generating function and moment generating function.

Discrete probability distributions: Uniform, Geometric, negative binomial, hypergeometric. Limiting/approximation cases.

Continuous probability distributions: uniform, exponential, beta, gamma, lognormal distributions along with their properties.

Two dimensional random variables (*discrete and continuous cases*): Joint p.m.f. and p.d.f., marginal and conditional distributions, properties of c.d.f., independence of variables, Theorems on sum and product of expectations of random variables, Conditional Expectation, Correlation and Regression. Trinomial distribution and its properties. Bivariate Normal Distribution and its properties.

STAT-MD-CC5-4-P **1 Credit**

(Descriptive Statistics III and Probability III) **PRACTICAL**

- Problems on trivariate data: regression line, multiple & partial correlation.
- Application problems based on discrete distributions.
- Application Problems based on continuous distributions.

Reference Books:

- Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1), World Press
- Johnson, N.I. & Kotz S.: Distributions in Statistics, John Wiley
- Ross S.M.: Introduction to Probability Models, Academic Press
- Mood A.M., Graybill F. & Boes D.C.: An Introduction to the Theory of Statistics (3rd ed), McGraw Hill
- Rao C.R.: Advanced Statistical Methods in Biometric Research, John Wiley
- Hogg R.V. & Craig A.T.: Introduction to Mathematical Statistics
- Rohatgi V.K.: An Introduction to Probability Theory & Mathematical Statistics, John Wiley
- Stuart G & Ord J.K.: Advanced Theory of Statistics (Vol 2), Charles Griffin
- Goon A. M., Gupta M. K. and Dasgupta B.: Fundamentals of Statistics (V-1), World Press.
- Bhattacharya, G.K. & Johnson R. A.: Concepts & Methods of Statistics, John Wiley
- Gupta, S.C., Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons

STATISTICS MINOR

STAT-MD-MC2-4-Th **3 Credits**

(Descriptive Statistics II & Probability II) **THEORY**

Bivariate data: Definition, scatter diagram, simple correlation, linear regression, principle of least squares, fitting of polynomial and exponential curves, correlation ratio, correlation index, intraclass correlation.

Rank correlation: Spearman's and Kendall's measures. (15)

Analysis of Categorical Data: Contingency table, independence & association of attributes. (5)

Random Variables: Definition of discrete and continuous random variables, cumulative distribution function (c.d.f.) and its properties (without proof), probability mass function (p.m.f.) and probability density function (p.d.f.). Expectation and Variance. Standard probability distributions: Discrete Uniform, Binomial, Poisson, and Normal. (25)

STAT-MD-MC2-4-P **1 Credit**

(Descriptive Statistics II & Probability II) **PRACTICAL**

List of Suggested Practical

- Problems based on analysis of bivariate data.
- Problems based on measures of rank correlation.
- Problems based on analysis of categorical data.
- Finding expectation, variance from a given probability distribution.
- Fitting of binomial distributions for n and p = q = 1/2.
- Fitting of binomial distributions for given n and p.
- Fitting of binomial distributions after computing mean and variance.
- Fitting of Poisson distributions for given value of mean.
- Fitting of Poisson distributions after computing mean.
- Application problems based on binomial distribution.
- Application problems based on Poisson distribution.
- Problems based on area property of normal distribution.
- To find the ordinate for a given area for normal distribution.
- Application based problems using normal distribution.

- Fitting of normal distribution when parameters are given.
- Fitting of normal distribution when parameters are not given.

Reference Books:

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. I, The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory (Vol-1), World Press.
- Miller, Irwin and Miller, Marylees: John E. Freunds Mathematical Statistics with Applications, (7th Edn.), Pearson Education, Asia.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint), Tata McGraw-Hill Pub. Co. Ltd.
- Tukey, J.W.: Exploratory Data Analysis, Addison-Wesley Publishing Co.
- Agresti, A.: Analysis of Ordinal Categorical Data, 2nd Edition, Wiley.
- Freedman, D., Pisani, R. and Purves, R.: Statistics, 4th Edition, W. W. Norton & Company.
- Chung, K.L.: Elementary Probability Theory with Stochastic Process, Springer / Narosa.
- Feller, W.: An Introduction to Probability Theory & its Applications, John Wiley.
- Parzen, E.: Modern Probability Theory and its Applications, John Wiley.
- Uspensky, J.V.: Introduction to Mathematical Probability, McGraw Hill.
- Cacoullos, T.: Exercises in Probability, Narosa.
- Rahman, N.A.: Practical Exercises in Probability and Statistics, Griffin.
- Ross, S.: A First Course in Probability, Prentice Hall.
- Hogg, R.V., Tanis, E.A. and Rao J.M.: Probability and Statistical Inference, Seventh Ed, Pearson Education, New Delhi.
- Myer, P.L.: Introductory Probability and Statistical Applications, Oxford & IBH Publishing, New Delhi.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint) John Wiley and Sons.
- Roychowdhury, S., Bhattacharya, D.: Statistics Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.
- Gupta, S.C., Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons

SEMESTER - V

STATISTICS MAJOR

STAT-MD-CC6-5-P **4 Credits**

(Project Work) **PRACTICAL**

Objective: The aim of the course is to initiate students to write and present a statistical report, under the supervision of a faculty, on some area of human interest. The project work will provide hands on training to the students to deal with data emanating from some real-life situation and propel them to dwell on some theory or relate it to some theoretical concepts.

STAT-MD-CC7-5-Th **3 Credits**

(Applications of Statistics I) **THEORY**

Demography:

Introduction: Sources of Population Data – Census data, Registration data and the errors in such data. Rates and ratios of vital events.

Measurements of Mortality: Crude Death rate, Specific Death Rate, Standardized death Rate, Case fatality rate and Cause of Death Rate, Infant Mortality Rate. (6)

Life tables: Descriptions of Complete Life Table and their uses, Cohort vs. Current Life Tables, Stable population and Stationary population, Construction of complete life table from population and death statistics.

Measurements of Fertility: Crude Birth Rate, General Fertility Rate, Age Specific Fertility Rate, Total Fertility Rate.

Measurement of Population Growth: Crude Rate of Natural Increase and Vital Index, Gross and Net Reproduction Rates. (12)

Index Numbers:

Price Index Numbers: Construction, Uses, Limitations, Tests for index numbers, Various formulae and their comparisons, Chain Index Number.

Some Important Indices: Consumer Price Index, Wholesale Price Index and Index of Industrial Production- methods of construction. Uses of Index numbers. (12)

Psychometry:

Scaling procedures: percentile scaling, Z scaling, T scaling, method of equivalent scores, Intelligence tests & IQ, Scaling ordinal data: Likert scaling, Thurstone Scaling. (15)

STAT-MD-CC7-5-P **1 Credit**

(Applications of Statistics I) **PRACTICAL**

- Mortality rates
- Life table
- Fertility rates and population growth
- Index Number
- Problems using different scaling

Reference Books:

- Goon, A.M., Gupta, M.K., Dasgupta, B. (2001): Fundamentals of Statistics (V-2), World Press.
- Spiegelman M. (1980): Introduction to Demography, Harvard University Press.
- Cox P.R. (1976): Demography, Cambridge University press.
- Shryock, H. S., Siegel, J. S. & Associates. (1976): The methods and materials of demography (4th ed.). U.S. Bureau of the Census.
- Preston, S. H., Heuveline, P. & Guillot, M. (2001): Demography: Measuring and modeling population processes. Blackwell Publishers.
- Siegel, J. S. (2002): Applied demography: Applications to business, government, law, and public policy. Academic Press.
- Croxton, F.E. and Cowden, D.J.: Applied General Statistics. Prentice-Hall.
- Allen, R. G. D. (1975): Index numbers in theory and practice. Macmillan.
- Mudgett, B. D. (1951): Index numbers. Wiley.
- Crocker, L. & Algina, J. (2008): Introduction to classical and modern test theory. Cengage Learning.
- McDonald, R. P. (1999): Test theory: A unified treatment. Psychology Press.
- Kline, P. (2000): The handbook of psychological testing (2nd ed.). Routledge.

STATISTICS MINOR

STAT-MD-MC3-5-Th **3 Credits**

(Statistical Inference I) **THEORY**

Basic concepts of Statistical Inference: population & sample, parameter & statistic, population distribution and sampling distribution. Point estimation, interval estimation and testing of hypothesis. Three useful distributions for statistical Inference: χ^2, t and F (derivations excluded). (5)

Point Estimation: Concepts of estimation, requirements of a good estimator, notions of mean square error, unbiasedness, bias-variance trade off, best linear unbiasedness and minimum variance unbiasedness. Properties of uniformly minimum variance unbiased estimators (UMVUE). Comparison of Estimators, Efficiency. Methods of Estimation: Method of moments, method of maximum likelihood estimation and statements of their small sample properties. Point estimators of the parameters of Binomial, Poisson, and univariate Normal distributions. (15)

Elements of hypothesis testing: Null and alternative hypotheses, simple & composite hypotheses, critical region, type I and type II errors, level of significance, size, power, p-value. Exact tests and confidence intervals: classical and p-value approaches. Tests relating to Binomial and Poisson distributions, Fisher's exact test. Chi-square tests for association, homogeneity and goodness of fit. Tests of hypotheses for the parameters of normal distribution (one sample and two sample problems), paired t-test. Combination of probabilities in tests of significance. (20)

Interval Estimation: Confidence Interval and Confidence Coefficient, Exact confidence interval for mean(s) and variance(s) for one and two sample problems under the Normal set-up. (5)

STAT-MD-MC3-5-P **1 Credit**

(Statistical Inference I) **PRACTICAL**

List of Suggested Practical

- Maximum Likelihood Estimation.
- Estimation by the method of moments.
- Test of significance for single proportion and difference of two proportions.
- Test of significance for single Poisson mean and difference of two Poisson means.
- Chi square tests for association, homogeneity and goodness of fit.
- Test of significance and confidence intervals for single mean and difference of two means.
- Test of significance and confidence intervals for single variance and ratio of two variances.

Reference Books

- Goon, A.M., Gupta, M.K. and Dasgupta, B.: Fundamentals of Statistics, Vol. 1. The World Press, Kolkata.
- Goon, A.M., Gupta, M.K. & Dasgupta, B.: An Outline of Statistical Theory, Vol-1. World Press.
- Rohatgi, V. K. and Saleh, A.K. Md. E.: An Introduction to Probability and Statistics. 2nd Edn. (Reprint). John Wiley and Sons.
- Hogg, R.V., Tanis, E.A. and Zimmerman, D. L.: Probability and Statistical Inference. Pearson Education.
- Johnson, R.A. and Bhattacharya, G.K.: Statistics-Principles and Methods, 4th Edn. John Wiley and Sons.
- Mood, A.M., Graybill, F.A. and Boes, D.C.: Introduction to the Theory of Statistics, 3rd Edn. (Reprint). Tata McGraw-Hill.
- Hogg, R.V., McKean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics, 8th Edition. Pearson.
- Gupta, S.C. and Kapoor, V.K. (2020): Fundamentals of Mathematical Statistics. Sultan Chand and Sons.
- Ramachandran, K.M. and Tsokos, C.P.: Mathematical Statistics with Applications. Academic Press.
- Roychowdhury, S., Bhattacharya, D.: Probability and Statistical Inference Theory and Practice, U.N. Dhur & Sons. Pvt. Ltd.

STAT-MD-MC4-5-P **4 Credits**

(Project Work) **PRACTICAL**

Objective: The aim of the course is to initiate students to write and present a statistical report, under the supervision of a faculty, on some area of human interest. The project work will provide hands on training to the students to deal with data emanating from some real-life situation and propel them to dwell on some theory or relate it to some theoretical concepts.

SEMESTER - VI

STATISTICS MAJOR

STAT-MD-CC7-6-Th **3 Credits**

(Applications of Statistics I) **THEORY**

Demography:

Introduction: Sources of Population Data – Census data, Registration data and the errors in such data. Rates and ratios of vital events.

Measurements of Mortality: Crude Death rate, Specific Death Rate, Standardized death Rate, Case fatality rate and Cause of Death Rate, Infant Mortality Rate. (6)

Life tables: Descriptions of Complete Life Table and their uses, Cohort vs. Current Life Tables, Stable population and Stationary population, Construction of complete life table from population and death statistics.

Measurements of Fertility: Crude Birth Rate, General Fertility Rate, Age Specific Fertility Rate, Total Fertility Rate.

Measurement of Population Growth: Crude Rate of Natural Increase and Vital Index, Gross and Net Reproduction Rates. (12)

Index Numbers:

Price Index Numbers: Construction, Uses, Limitations, Tests for index numbers, Various formulae and their comparisons, Chain Index Number.

Some Important Indices: Consumer Price Index, Wholesale Price Index and Index of Industrial Production- methods of construction. Uses of Index numbers. (12)

Psychometry:

Scaling procedures: percentile scaling, Z scaling, T scaling, method of equivalent scores, Intelligence tests & IQ, Scaling ordinal data: Likert scaling, Thurstone Scaling. (15)

STAT-MD-CC7-6-P **1 Credit**

(Applications of Statistics I) **PRACTICAL**

- Mortality rates
- Life table
- Fertility rates and population growth
- Index Number
- Problems using different scaling

Reference Books:

- Goon, A.M., Gupta, M.K., Dasgupta, B. (2001): Fundamentals of Statistics (V-2), World Press.
- Spiegelman M. (1980): Introduction to Demography, Harvard University Press.
- Cox P.R. (1976): Demography, Cambridge University press.
- Shryock, H. S., Siegel, J. S. & Associates. (1976): The methods and materials of demography (4th ed.). U.S. Bureau of the Census.
- Preston, S. H., Heuveline, P. & Guillot, M. (2001): Demography: Measuring and modeling population processes. Blackwell Publishers.
- Siegel, J. S. (2002): Applied demography: Applications to business, government, law, and public policy. Academic Press.
- Croxton, F.E. and Cowden, D.J.: Applied General Statistics. Prentice-Hall.
- Allen, R. G. D. (1975): Index numbers in theory and practice. Macmillan.
- Mudgett, B. D. (1951): Index numbers. Wiley.
- Crocker, L. & Algina, J. (2008): Introduction to classical and modern test theory. Cengage Learning.
- McDonald, R. P. (1999): Test theory: A unified treatment. Psychology Press.
- Kline, P. (2000): The handbook of psychological testing (2nd ed.). Routledge.

STAT-MD-CC8-6-Th **3 Credits**

(Applications of Statistics II) **THEORY**

Time Series Analysis:

Introduction: Examples of time series from various fields, Components of a times series, Additive and Multiplicative models. Stationary and Non-stationary time series.

Trend and Seasonal Components: Estimation of trend by moving averages and curve fitting - polynomial, exponential, Detrending. Estimation of seasonal component by ratio to moving average method, ratio to trend method, Deseasonalization. (7)

Stationary time series, autocorrelation function, moving average process of general order, Autoregressive process of order 1. (10)

Statistical Quality Control:

Introduction: Concepts of Quality and Quality Control, Process Control and Product Control.

Process Control: Control Charts and their uses, Choice of Subgroup sizes, Construction of control charts by attributes (p, c, np) (including unequal subgroup size) and variables $(\bar{X}, R)$. (6)

Product Control: Producer's Risk, Consumer's Risk, process average, acceptable quality level, Acceptance Sampling Plan, Single and Double sampling plans by attributes, their OC, ASN and ATI, LTPD and AOQL.

Single sampling plan for inspection by variables (one-sided specification, known and Unknown σ case). (8)

Statistical learning:

Overview of statistical learning, unsupervised and supervised learning, Validation, Training and Testing, Dimensionality reduction, Grouping of observations.

Unsupervised learning: cluster analysis, Hierarchical Methods and partitioning (K-means clustering method).

Supervised learning: Idea of classification, Regression based algorithms (linear classifiers, Decision trees, random forest, logistic regression, linear, polynomial, decision tree regression).

Dimension reduction Method: Principal component Analysis. (14)

STAT-MD-CC8-6-P **1 Credit**

(Applications of Statistics II) **PRACTICAL**

- Trend determination by method of moving averages and by fitting polynomial of appropriate degree.
- Computation of seasonal indices by ratio to trend & ratio to moving average method.
- Control charts for attribute and variable.
- Sampling Inspection plan.
- Cluster Analysis.
- Logistic regression.
- Principal component analysis.

Reference Books:

- Goon, A.M., Gupta, M.K., Dasgupta, B. (2001): Fundamentals of Statistics (V-2), World Press.
- Kendall M.G. (1976): Time Series, Charles Griffin.
- Chatfield C. (1980): The Analysis of Time Series –An Introduction, Chapman & Hall.
- Box, G. E. P., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015): Time series analysis: Forecasting and control (5th ed.). Wiley.
- Hyndman, R. J., & Athanasopoulos, G. (2021): Forecasting: Principles and practice (3rd ed.). OTexts.
- Montgomery, D. C. (2019): Introduction to statistical quality control (8th ed.). Wiley.
- Duncan A.J. (1953): Quality Control and Industrial Statistics, Richard D Irwin.
- Cowden D.J. (1957): Statistical Methods in Quality Control, Prentice Hall.
- Jiawei Han, Micheline Kamber, Jian Pei: Data Mining concepts and technique.
- James, G., Witten, D., Hastie, T., &Tibshirani, R. (2023): An introduction to statistical learning: With applications in Python (2nd ed.). Springer.
- Hastie, T., Tibshirani, R., & Friedman, J. (2009): The elements of statistical learning: Data mining, inference, and prediction (2nd ed.). Springer.

STATISTICS MINOR

STAT-MD-MC5-6-Th **3 Credits**

(Design of Experiments I and Sample Survey I) **THEORY**

Design of Experiments I:

Analysis of Variance: Factors, types and effects; Fixed, random and mixed effects models; Analysis of one-way and two-way classified data with equal number of observations in each cell (Fixed Effects Models only). (10)

Experimental designs: Treatments, Experimental units & Blocks, Experimental error, Basic principles of Design of Experiments (Fisher). (2)

Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model, Applications of the techniques of ANOVA to the analysis of the above designs. Missing plot techniques in RBD and LSD. Uniformity trial experiments and comparison of designs. (10)

Sample Survey I:

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principle of sample survey, simple random sampling with and without replacement, random numbers, procedure of selecting a sample, estimates of population mean, total and proportion, standard errors of these estimates, estimates of their standard errors. (15)

Stratified random sampling: Technique, estimates of population mean and total, variances of these estimates, proportional and optimum allocations and their comparison with SRS. (4)

Two-stage sampling (with primary units of equal size and equal selection probability at each stage): unbiased estimation of population mean and total. Ideas of snowball sampling, purposive sampling. (4)

STAT-MD-MC5-6-P **1 Credit**

(Design of Experiments I and Sample Survey I) **PRACTICAL**

List of Suggested Practical

- Analysis of Variance of a one-way classified data (fixed effects model).
- Analysis of Variance of a two-way classified data with one observation per cell (fixed effects model).
- Analysis of Variance of a two-way classified data with more than one observation per cell (fixed effects model).
- Analysis of a CRD.
- Analysis of an RBD.
- Analysis of an LSD.
- Analysis of an RBD with one missing observation.
- Analysis of an LSD with one missing observation.
- To select a simple random sample with and without replacement.
- Simple random sampling – estimation of population mean, total and proportion; estimation of related standard error.
- Estimate the sample size for SRSWOR.
- Stratified Sampling –estimation of population mean and total, allocation of sample to strata by proportional and Neyman's methods, Comparison of the efficiencies of the above two methods relative to SRS.
- Estimation of gain in precision in stratified sampling.
- Two-stage Sampling – estimation of population mean and total.

Reference Books:

- Renchner, A. C. And Schaalje, G. B.: Linear Models in Statistics (Second edition), John Wiley and Sons.
- Scheffe, H.: The Analysis of Variance, John Wiley.
- Cochran, W.G. and Cox, G.M.: Experimental Design. Asia Publishing House.
- Das, M.N. and Giri, N.C.: Design and Analysis of Experiments. Wiley Eastern Ltd.
- Kempthorne, O.: The Design and Analysis of Experiments. John Wiley.
- Montgomery, D. C.: Design and Analysis of Experiments, John Wiley.

- Wu, C. F. J. And Hamada, M.: Experiments, Analysis, and Parameter Design Optimization (Second edition), John Wiley.
- Dean, A.M. and Voss, D.: Design and Analysis of Experiments. Springer Texts in Statistics.
- Goon, A.M., Gupta, M.K., Das Gupta, B.: An Outline of Statistical Theory, Vol-II, World Press, Calcutta.
- Goon A.M., Gupta M.K. and Dasgupta B.: Fundamentals of Statistics, Vol-II, World Press.
- Cochran, W.G.: Sampling Techniques (3^{rd} Ed.), Wiley Eastern.
- Sukhatme, P.V., Sukhatme, B.V. Sukhatme, S. Asok, C.: Sampling Theories of Survey With Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Murthy, M.N.: Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P.: Sample Survey Theory, Narosa Publishing House.

STAT-MD-MC6-6-Th **3 Credits**

(Descriptive Statistics III and Probability III) **THEORY**

Descriptive Statistics III (15)

Multivariate frequency distribution: multivariate data, multiple regression, multiple correlation, partial correlation coefficient, Particular case with three variates.

Probability III (30)

Moments, Quantiles, Skewness and Kurtosis (including discussions of these measures for Binomial, Poisson and Univariate Normal Distributions). Generating functions – probability generating function and moment generating function.

Discrete probability distributions: Uniform, Geometric, negative binomial, hypergeometric. Limiting/approximation cases.

Continuous probability distributions: uniform, exponential, beta, gamma, lognormal distributions along with their properties.

Two dimensional random variables (*discrete and continuous cases*): Joint p.m.f. and p.d.f., marginal and conditional distributions, properties of c.d.f., independence of variables, Theorems on sum and product of expectations of random variables, Conditional Expectation, Correlation and Regression. Trinomial distribution and its properties. Bivariate Normal Distribution and its properties.

STAT-MD-MC6-6-P **1 Credit**

(Descriptive Statistics III and Probability III) **PRACTICAL**

- Problems on trivariate data: regression line, multiple & partial correlation.
- Application problems based on discrete distributions.
- Application Problems based on continuous distributions.

Reference Books:

- Goon A.M., Gupta M.K. & Dasgupta B.: An Outline of Statistical Theory (Vol-1), World Press
- Johnson, N.I. & Kotz S.: Distributions in Statistics, John Wiley
- Ross S.M.: Introduction to Probability Models, Academic Press
- Mood A.M., Graybill F. & Boes D.C.: An Introduction to the Theory of Statistics (3rd ed), McGraw Hill
- Rao C.R.: Advanced Statistical Methods in Biometric Research, John Wiley
- Hogg R.V. & Craig A.T.: Introduction to Mathematical Statistics
- Rohatgi V.K.: An Introduction to Probability Theory & Mathematical Statistics, John Wiley
- Stuart G & Ord J.K.: Advanced Theory of Statistics (Vol 2), Charles Griffin
- Goon A. M., Gupta M. K. and Dasgupta B.: Fundamentals of Statistics (V-1), World Press.
- Bhattacharya, G.K. & Johnson R. A.: Concepts & Methods of Statistics, John Wiley
- Gupta, S.C., Kapoor, V.K.: Fundamentals of Mathematical Statistics, Sultan Chand & Sons

QUESTION PATTERNS

Four-year B.Sc. (Honours and Honours with Research) Course
&
Three-year B.Sc. Multidisciplinary Course
(Under Curriculum & Credit Framework, 2022)

Theoretical

Full Marks: 75 (Applicable for all papers with 3 Credits)

(a) Objective type: 5 questions × 2 marks = 10 marks

(5 questions are to be attempted out of 8 choices carrying 2 marks each)

(b) Short answer type: 4 questions × 5 marks = 20 marks

(4 questions are to be attempted out of 6 choices carrying 5 marks each)

(c) Broad answer type: 3 questions × 15 marks = 45 marks

(3 questions are to be attempted out of 5 choices carrying 15 marks each)

Full Marks: 50 (Applicable for all papers with 2 Credits)

(a) Objective type: 5 questions × 2 marks = 10 marks

(5 questions are to be attempted out of 8 choices carrying 2 marks each)

(b) Short answer type: 4 questions × 5 marks = 20 marks

(4 questions are to be attempted out of 6 choices carrying 5 marks each)

(c) Broad answer type: 2 questions × 10 marks = 20 marks

(2 questions are to be attempted out of 3 choices carrying 10 marks each)

Practical

Full Marks: 25 (Applicable for all papers with 1 Credit)

Duration: *2 Hours*

(a) Problems: 16 marks

(b) Viva-voce: 5 marks

(c) Practical Note Book: 4 marks

Full Marks: 50 (Applicable for all papers with 2 Credits)

Duration: *4 Hours*

(a) Problems: 40 marks

(b) Viva-voce: 5 marks

(c) Practical Note Book: 5 marks

Full Marks: 100 (Applicable for all papers with 4 Credits)

Duration: *5 Hours*

(a) Problems: 80 marks

(b) Viva-voce: 10 marks

(c) Practical Note Book: 10 marks

Notes:

1. The candidates will be required to answer all the questions in the Practical Papers.
2. Practical Examination for B.Sc. Four-year Statistics Major to be conducted in away centres simultaneously on the basis of single question paper in presence of external examiners.
3. Practical Examination for B.Sc. Four-year Statistics Major papers STAT-H-SEC1-1, STAT-H-SEC3-3 and STAT-H-CC13-6 to be conducted in batches in away centres using Computers only.
4. Practical Examination for B.Sc. Four-year Statistics Minor and IDC to be conducted in home centres by internal examiners only.
5. Practical Examination for Three-year Statistics Major, Minor and IDC to be conducted in home centres by internal examiners only.
6. Project Examination for Three-year Statistics Major and Minor to be conducted in home centres by internal examiners only.