UNIVERSITY OF DELHI

CNC-II/093/1/EC-1276/25/3(ii)
Dated: 12.02.2026

NOTIFICATION

Sub: Amendment to Ordinance V

(Ref: ECR 24-13/ dated 12.07.2025)

In continuation of Council Branch Notification No. CNC-II/093/1/EC-1276/25/3 dated 31.07.2025, the revised syllabus of M.A/MSc. Statistics under the Faculty of Mathematical Science based on Postgraduate Curriculum Framework 2024 is notified herewith for the information of all concerned as per ***Annexure-1.***

REGISTRAR

Annexure-1

After changes

Curricular Structure and Syllabi of Courses

First Year of Two Year M.A./M.Sc. Statistics Programme

Under

PG Curricular Framework - Level 6

Proposed Syllabus
(Effective from AY 2025-26 based on NEP-2020)

Department of Statistics
Faculty of Mathematical Sciences
University of Delhi, Delhi – 110007

Programme Objectives and Outcomes

Programme Objectives:

The primary objectives of the M.A./M.Sc. Statistics Programme are to nurture students by enabling them to:

- Develop the aptitude to apply statistical tools to diverse data-generating fields and real-life problems.
- Gain the skills required to handle large datasets and perform data analysis using statistical software and programming languages.
- Acquire a wide range of statistical competencies- including problem-solving, project work, and presentation skills- so they can take on significant roles across various employment sectors and research fields.

Programme Outcomes:

Upon successful completion of the programme, students will be able to:

- Gain sound knowledge of both theoretical and practical aspects of Statistics.
- Apply statistical modelling and computational techniques effectively in practical scenarios.
- Explain complex statistical concepts to non-statisticians clearly and accurately.
- Manage and analyse large datasets using appropriate computational tools, and use the results to propose practical improvements.
- Pursue diverse career opportunities in research, industry, and academia.

M.A./M.Sc. Statistics Programme Details

Programme Structure

Two Year M.A./M.Sc. Statistics programme is a course divided into 2+2 semesters. A student is required to complete minimum **22** credits for completion of each semester.

Part	Year	Semester	Semester	Level
Part – I	First Year	Semester I	Semester II	6
Part – II	Second Year	Semester III	Semester IV	6.5

Course Credit Scheme of Part-I:

Curricular Structure of First Year of Two Year PG Programme (In each Semester, 3 Core and either 2 DSE or 1 DSE + 1 GE are required)									
Semester	**Discipline Specific Core (DSC)**		**Discipline Specific Elective (DSE)**		**Generic Elective (GE)**		**Skill Based/Specialized Laboratory**		**Total Credits**
	No. of Papers	Credits	No. of Papers	Credits	No. of Papers	Credits	No. of Papers	Credits	
I	3	12	2	8	0	0	1	2	**22**
			1	4	1	4			
II	3	12	2	8	0	0	1	2	**22**
			1	4	1	4			
Total Credits for First Year of Two Year PG Programme									**44**

Semester Wise Details:

Semester I of Two Year PG Programme					
Discipline Specific Core Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
DSC 1a	Probability Theory	3	1	0	4
DSC 1b	Statistical Methodology	3	1	0	4
DSC 1c	Survey Sampling	3	1	0	4

Discipline Specific Elective (DSE) Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
DSE 1a	Analysis	3	1	0	4
DSE 1b	Time Series Analysis	3	0	1	4
DSE 1c	Biostatistics	3	0	1	4
DSE 1d	Official and National Development Statistics	3	1	0	4

Generic Elective (GE) Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
GE 1a	Statistical Computing using R	3	0	1	4

Skill Based/Specialized Laboratory (SB) Courses					
Course code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
SB 1a	Data Analysis using Excel	0	0	2	2

Semester II of Two Year PG Programme					
Discipline Specific Core (DSC) Core Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
DSC 2a	Statistical Inference	3	1	0	4
DSC 2b	Design of Experiments	3	1	0	4
DSC 2c	Stochastic Processes	3	1	0	4

Discipline Specific Elective (DSE) Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
DSE 2a	Linear Algebra	3	1	0	4
DSE 2b	Non-Parametric Inference	3	0	1	4
DSE 2c	Statistical Quality Control	3	0	1	4
DSE 2d	Reliability Theory	3	1	0	4
DSE 2e	Computational Techniques	2	0	2	4

Generic Elective (GE) Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
GE 2a	Statistics for Research and Management Studies	2	0	2	4

Skill Based/Specialized Laboratory (SB) Courses					
Course Code	**Course Title**	**Credits**			
		Theory	**Tutorial**	**Practical**	**Total**
SB 1a	Data Analysis using Python	0	0	2	2

First Year of Two Year M.A./M.Sc. Statistics Programme

Semester I

Discipline Specific Core (DSC) Courses

Discipline Specific Core (DSC) Course 1a: Probability Theory

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSC 1a: Probability Theory	**4**	**3**	**1**	**0**	**NIL**	**NIL**

Course Objectives:

- To introduce and emphasize the role of measure theory in probability theory.
- To develop the understanding of Weak Law of Large Numbers, Strong Law of Large Numbers and the Central Limit Theorem with their applications.

Course Learning Outcomes: After successfully completing this course, students will be able to apply:

- Concepts of random variables, sigma-fields, probability distributions, and the independence of random variables related to measurable functions.
- Skills in working with measurable functions and sequences of random variables.
- The weak laws of large numbers in practical scenarios.
- The strong laws of large numbers to solve real-world problems.
- The central limit theorem in data analysis and interpretation.
- Principles of convergence and modes of convergence to assess statistical data.
- Characteristic functions, as well as the uniqueness, inversion, and Levy continuity theorems, to advanced probability problems.

Unit I (10 Hours)

Classes of sets, fields, σ -fields, minimal σ -field, Borel σ – field in R^K, sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue measures on R^K.

Unit II (11 Hours)

Measurable functions, Random variables, sequence of random variables, Integration of a measurable function with respect to a measure. Monotone convergence theorem, Fatou's lemma, Dominated convergence theorem. Characteristic functions, uniqueness/inversion/Levy continuity theorems.

Unit III (12 Hours)

Markov's, Chebychev's and Kolmogorov's inequalities, Modes of stochastic convergence, Jenson, Liapounov, holder's and Minkowsky's inequalities, Sequence of random variables and modes of convergence (convergence in distribution, in probability, almost surely, and quadratic mean) and their interrelations. Statement of Slutsky's theorem, Borel-Cantelli lemma and Borel 0-1 law.

Unit IV (12 Hours)

Concept of Independence, Laws of large numbers, Chebyshev's and Khinchine's WLLN, necessary and sufficient condition for the WLLN, strong law of large numbers and Kolmogorov's theorem, Central limit theorem, Lindeberg and Levy and Liapunov forms of CLT.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Ash, R.B. and Doléans-Dade, C.A. (1999). *Probability and Measure Theory*, Academic Press.
2. Bhat, B.R. (1999). *Modern Probability Theory*, New Age International Publishers.
3. Billingsley, P. (2017). *Probability and measure*, John Wiley & Sons.
4. Rohatgi, V.K., and Saleh, A.K.Md.E. (2015). *An introduction to probability and statistics*, John Wiley & Sons.

Suggested Readings:

1. Capinski, M. and Zastawniak, T. (2001). *Probability through problems*, Springer.
2. Chung, K.L. (1974). *A Course in Probability Theory*, Academic Press.
3. Feller, W. (1968). *An Introduction to Probability Theory and its Applications*, Vol. 1, John Wiley & Sons.
4. Parzen, E. (1960). *Modern Probability Theory and its Application*, John Wiley & Sons.

Discipline Specific Core (DSC) Course 1b: Statistical Methodology

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSC 1b: Statistical Methodology	4	3	1	0	NIL	NIL

Course Objective:

- To provide a thorough theoretical grounding in different type of distributions, non-central distributions, censoring, delta method, robust procedures etc.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Formulate the mathematical/statistical models for real data sets arising in various fields in order to analyse in respect of various useful characteristics of the populations.
- Understand how to use non-central distributions in real life problems.
- Understand different types of censoring schemes and their applications.
- Work with incomplete data which is a challenging problem in today's life.

Unit I (10 Hours)

Brief review of basic distribution theory, Symmetric distributions, Truncated distributions, Compound distributions, Mixture of distributions, Generalized power series distributions, Exponential family of distributions.

Unit II (12 Hours)

Characterization of distributions (Geometric, negative exponential, normal, gamma), Non-central Chi-square, t and F distributions and their properties, Concept of censoring. Approximating distributions, Delta method and its applications, Approximating distributions of sample moments, limiting moment generating function, Poisson approximation to negative binomial distribution.

Unit III (12 Hours)

Order statistics-their distributions and properties. Joint and marginal distributions of order statistics. Extreme values and their asymptotic distributions (statement only) with applications. Tolerance intervals, coverage of $(X_{(r)}, X_{(s)})$. Generic theory of regression, fitting of polynomial regression by orthogonal methods, multiple regression, examination of regression equation.

Unit IV (11 Hours)

Robust procedures, Robustness of sample mean, Sample standard deviation, Chi-square test and Student's t-test. Sample size determination for testing and estimation procedures (complete and censored data) for normal, exponential, Weibull and gamma distributions.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Biswas, S. (1992). *Topics in Statistical Methodology*, Wiley-Blackwell.
2. David, H.A. and Nagaraja, H.N. (2003). *Order Statistics*, John Wiley & Sons.
3. Mukhopadhyay, P. (2015). *Mathematical Statistics*, New Central Book Agency.
4. Rohatgi, V.K. and Saleh, A.K.Md.E. (2015). *An Introduction to Probability and Statistics*, John Wiley & Sons.

Suggested Readings:

1. Arnold, B.C., Balakrishnan, N. and Nagaraja, H.N. (1992). *A First Course in Order Statistics*, John Wiley & Sons.
2. Dudewicz, E.J. and Mishra, S.N. (1988). *Modern Mathematical Statistics*, John Wiley & Sons.
3. Huber, P.J. (1981). *Robust Statistics*, John Wiley & Sons.
4. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). *Discrete Univariate*, John Wiley & Sons.
5. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). *Continuous Univariate Distributions*, John Wiley & Sons.
6. Rao, C.R. (1973). *Linear Statistical Inference and Its Applications*, John Wiley & Sons.
7. Rohatgi, V.K. (1984). *Statistical Inference*, John Wiley & Sons.

Discipline Specific Core (DSC) Course 1c: Survey Sampling

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 hours)		
DSC 1c: Survey Sampling	**4**	**3**	**1**	**0**	**NIL**	**NIL**

Course Objectives:

- Learn key tools and techniques for selecting representative samples from a target population.
- Understand how sampling decisions depend on study objectives and the characteristics of the population

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Understand the distinctive features of sampling schemes and its related estimation problems
- Learn about various approaches (design based and model-based) to estimate admissible parameters; with and without replacement sampling scheme, sampling with varying probability of selection.
- Learn about the methods of post–stratification (stratified sampling) and controlled sampling and also double sampling procedure with unequal probability of selection.
- Apply the applications of various sampling methods; systematic, stratified and cluster sampling.
- Apply the various methods and techniques of randomized response techniques

Unit I (12 Hours)

Basic ideas and distinctive features of sampling, Probability sampling designs, sampling schemes, inclusion probabilities and estimation. Review of important results in simple and stratified random sampling, Fixed (Design-based) and Superpopulation (model based) approaches.

Unit II (11 Hours)

Sampling with varying probabilities (unequal probability sampling) with or without replacement: pps, πps and non- πps sampling methods and estimation based on them, Nonnegative variance estimation.

Unit III (11 Hours)

Two-way stratification, post-stratification, controlled sampling, Estimation based on auxiliary data (involving one or more auxiliary variables) under design-based and model-based approaches, estimation of domain mean.

Unit IV (11 Hours)

Systematic sampling and its application to structured populations, Cluster sampling (with varying sizes of clusters), Two-stage sampling (with varying sizes of first-stage units), Warner's and Simmons' randomized response techniques for one qualitative sensitive characteristic.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Cochran, W.G. (2011). *Sampling Techniques*, John Wiley & Sons.
2. Murthy M.N. (1977). *Sampling Theory and Statistical Methods*, Statistical Publishing Society.
3. Singh, D. and Chaudhary, F.S. (2015). *Theory and Analysis of Sample Survey Designs*, New Age International Publisher.

Suggested Readings:

1. Kish, L. (1965). *Survey Sampling*, John Wiley & Sons.
2. Latpate, R., Kshirsagar, Gupta, V.K. and Chandra, G. (2020). *Advanced Sampling Methods*, Springer.
3. Mukhopadhyay, P. (2009). *Theory and Methods of Survey Sampling*, Prentice Hall of India.
4. Rao, J.N.K. and Molina, I. (2015). *Small Area Estimation*, John Wiley & Sons.
5. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). *Sampling Theory of Surveys with Applications*, Iowa State University Press.
6. Wu, C. and Thompson, M.E. (2019). *Sampling Theory and Practice*, Springer.

Discipline Specific Elective (DSE) Courses

Discipline Specific Elective (DSE) Courses 1a: Analysis

Course Title and Code	Credits	Credit Distribution of Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSE 1a: Analysis	4	3	1	0	NIL	NIL

Course Objectives:

- To introduce students the knowledge of real field and complex field with their properties and relativity between complex plane and real line.
- To provide students grounds for Probability Theory and help in theoretical research in Statistics.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Understand existence of integral and their evaluation.
- Apply convergence theorems of sequence and series of real valued function and complex valued functions.
- Understand change of multiple integrals into line integral.
- Learn how apply real and complex-analytic methods to problems in probability theory.
- Understand complex region and relativity between complex plane and real line.
- Analyze power series, Laurent series, and residue calculus.
- Solve contour integrals.
- Gain exposure to challenging exercises that deepen theoretical understanding.

Unit I (10 Hours)

Functions of bounded variation, Riemann integration and Riemann-Stieltjes integration, Statement of the standard property and problem based on them, Multiple integrals, repeated integrals, Change of variables in multiple integration.

Unit II (11 Hours)

Differentiation under integral sign, Leibnitz rule, Dirichlet integral, Liouville's extension, Uniform convergence of sequence of functions and series of functions, Cauchy's criteria and Weirstrass M-test, Maxima-minima of functions of several variables.

Unit III (12 Hours)

Properties of complex numbers, Region in complex plane, Limit, continuity and differentiability of function of complex variables, Analytic function, Contour integration, Cauchy integral formula, Liouville's theorem, Fundamental theorem of Algebra.

Unit IV (12 Hours)

Power series and radius of convergence, Taylor's and Laurent's series, Singular points and their types, Residue at singular point and residue at infinity, Cauchy residue theorem, Evaluation of real integrals involving sine and cosine using residue.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Brown, J.W. and Chirchill, R.V. (2009). *Complex variables and Applications,* McGraw Hill.
2. Rudin, W. (1985). *Principles of Mathematical Analysis,* McGraw Hill.

Suggested Readings:

1. Bak, J. and Newman, D. J. (1997). *Complex Analysis,* Springer.
2. Bartle, R.G. (1976). *Elements of Analysis,* John Wiley & Sons.
3. Rose, K.A. (2004). *Elementary Analysis: The Theory of Calculus,* Springer.

Discipline Specific Elective (DSE) Course 1b: Time Series Analysis

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (00 Hours)	Practical (30 Hours)		
DSE 1b: Time Series Analysis	4	3	0	1	NIL	NIL

Course Objectives:

- To teach the time series modelling and the concept of forecasting and future planning.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Time series analysis concepts to practical data scenarios.
- Techniques to identify and analyze trends and seasonality.
- Various time series models, including MA, AR, ARMA, and ARIMA, for data modeling.
- Time series models for effective forecasting.
- Information criteria (AIC, BIC) to select the most suitable models.
- Yule-Walker equations to analyze AR processes.
- Methods to address non-stationarity in time series data.
- The random walk model and conduct the Dickey-Fuller test for unit root analysis.

Unit I (10 Hours)

Time series as a stationary or nonstationary stochastic process, sample autocovariance function (ACVF) and autocorrelation function (ACF) at lag k, partial autocorrelation function (PACF), correlogram, lag operators and linear filters, Ergodicity and Stationarity.

Unit II (12 Hours)

Wald decomposition, Generic linear process and its ACVF, ACF. Autoregressive (AR) process, moving average (MA) process, ACF and PACF for AR and MA processes, Yule-Walker equations for AR processes.

Unit III (12 Hours)

Stationarity and invertibility conditions, ARIMA (p,d,q) model, estimation of parameters for AR, MA, ARMA and ARIMA processes, identification of processes with ACF PACF, Model estimation techniques-AIC, AICC, BIC, etc.

Unit IV (11 Hours)

Forms of non-stationarity in time series, random walk model, Dickey-Fuller test for unit root. ARCH and GARCH Processes, order identification, estimation, diagnostic.

Essential Readings:

1. Box, G.E.P., Jenkins, G.M., Reinsel, G.C., Ljung, G.M. (2015). *Time Series Analysis-Forecasting and Control*, John Wiley & Sons.
2. Brockwell, P.J. and Davies, R.A. (2009). *Introduction to Time Series and Forecasting*, Springer.

Suggested Readings:

1. Chatfield, C. (1975). *The Analysis of Time series: Theory and Practice*, Chapman & Hall.
2. Chatfield, C. (2003). *Analysis of Time Series, An Introduction*, CRC Press.
3. Jonathan, D.C. and Kung, S.C. (2008). *Series Analysis with Application in R*. Springer
4. Kendall, M. G. and Ord, J. K., *Time Series*, Edward Arnold.
5. Montgomery, D.C. and Johnson, L.A. (1977). *Forecasting and Time series Analysis*, McGraw Hill.
6. Montgomery, D.C., Jennings, C. and Kulahci, M. (2016). *Introduction to Time Series Analysis and Forecasting*, John Wiley & Sons.
7. Shumway, R.H. and Stoffer, D.S. (2017). *Time Series Analysis and Its Applications: With R Examples*, Springer.

List of Practicals:

1. Calculate and plot descriptive statistics (mean, variance, autocorrelation, partial autocorrelation), create time plots.
2. Identify potential trends and seasonality.
3. Identify potential ARIMA(p,d,q) models based on ACF/PACF plots.
4. Identify potential ARIMA(p,d,q) models based on unit root tests.
5. Compare the performance of different ARIMA models (e.g., different orders) using information criteria (AIC, BIC).
6. Implementing Dickey-Fuller (or other unit root) tests on various datasets to determine stationarity.

Discipline Specific Elective (DSE) Course 1c: Biostatistics

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (00 Hours)	Practical (30 Hours)		
DSE 1c: Biostatistics	**4**	**3**	**0**	**1**	**NIL**	**NIL**

Course Objectives:

- To illustrate modelling approach for analysis of survival data in order to meet need of Statisticians in Pharmaceutical and bio-medical research sector.
- To guide scientists, clinicians and students for analysing their own data.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Develop understanding of time-to-event data in Biomedical Sciences.
- Summarizing clinical data using displays, parametric and non- parametric approaches.
- Understanding concepts of conditional and inverse probabilities as applied to survival data.
- Establishing meaningful relationships for causative and consequential health factors.
- Understand survival patterns in presence and in absence of censoring.
- Account for censored patterns and their implications.
- Estimation of failure and hazard forms based on patient data records.
- Formulate and interpret stochastic models for specific-disease data sets.
- Comprehend basis and construction of clinical trials for different stages.
- Analyze concept of Biometric genetics.

Unit I (11 Hours)

Analysis of Medical, Epidemiologic and Clinical Data: Studying association between a disease and a characteristic: (a) Types of studies in Epidemiology and Clinical Research (i) Prospective study (ii) Retrospective study (iii) Cross-sectional data, (b) Dichotomous Response and Dichotomous Risk Factor: 2x2 Tables (c) Expressing relationship between a risk factor and a disease (d) Inference for relative risk and odds ratio for 2x2 table, Sensitivity, specificity and predictivities. Clinical Trials: Its Planning and its Four Phases.

Unit II (11 Hours)

Special Survival Features: Censoring and its types. Study time and Patient time. Survival Analysis: Survival Distributions and their Properties *viz.* Exponential, Weibull, Gamma, Rayleigh and Lognormal. Estimation of Survivor and Hazard Functions: Life Table, Kaplan-Meier and Nelson-Aalen Estimates. Estimating Median and Survival Times. Estimation of Mean survival time and variance for Type I and Type II Censored data with examples.

Unit III (11 Hours)

Cox-Proportional Hazards Model: Its Linear Component, Fitting, Hypothesis Tests. Estimating Hazard and Survivor Function. Kaplan Meier Estimate, Hazard and Cumulative Incidence Functions, Modelling. Cause Specific Hazard and Incidence, Model Checking. Sample Size Requirements for a Survival Study.

Unit IV (12 Hours)

Multiple Factor Hypothesis for Process of Heredity. Medelian Population: Gene Frequency and Genotype Frequency. Hardy Weinberg Law: Multiple Alleles, Two or More Pairs of Genes, Linkage of Genes, Sex Linked Genes. Influence of Gene Frequencies on Population Mean. Breeding Value of Genotypes. Dominance Deviation.

Essential Readings:

1. Biswas, S. (1995). *Applied Stochastic Processes: A Biostatistical and Population Oriented Approach*, Wiley Eastern Ltd.
2. Cox, D.R. and Oakes, D. (1984). *Analysis of Survival Data*, Chapman and Hall.
3. Dabholkar A.R. (1999). *Elements of Bio Metrical Genetics*. Concept Publishing Co., New Delhi.
4. Indrayan, A. and Malhotra, R.K. (2018). *Medical Biostatistics*. Chapman & Hall/CRC Press.
5. Kestenbaum, B. (2019). *Epidemiology and Biostatistics: An Introduction to Clinical Research*, Springer.
6. Robert F. Woolson (1987). *Statistical Methods for the analysis of biomedical data*, John Wiley & Sons.

Suggested Readings:

1. Collett, D. (2003). *Modelling Survival Data in Medical Research*, Chapman & Hall/CRC.
2. Elandt Johnson R.C. (1971). *Probability Models and Statistical Methods in Genetics*, John Wiley & Sons.
3. Ewens, W. J. (1979). *Mathematics of Population Genetics*, Springer Verlag.
4. Ewens, W.J. and Grant, G.R. (2001). *Statistical methods in Bio informatics: An Introduction*, Springer.
5. Friedman, L.M., Furburg, C. and DeMets, D.L. (1998). *Fundamentals of Clinical Trials*, Springer Verlag.
6. Gross, A.J. And Clark V.A. (1975). *Survival Distribution; Reliability Applications in Biomedical Sciences*, John Wiley & Sons.
7. Indrayan, A. (2008). *Medical Biostatistics*, Chapman & Hall/CRC.
8. Lee, Elisa, T. (1992). *Statistical Methods for Survival Data Analysis*, John Wiley & Sons.
9. Li, C.C. (1976). *First Course of Population Genetics*, Boxwood Press.
10. Liu Xian. (2012). *Survival Analysis: Model and Applications.* Wiley.
11. Miller, R.G. (1981). *Survival Analysis*, John Wiley & Sons.
12. Tattar P.N and Vaman H.J. (2023). *Survival Analysis*. CRC Press.

List of Practicals:

1. Interpreting clinical Trial data.
2. Sample size estimation in clinical Trials.
3. Plotting Survival and Hazard Curves for different parameter combinations in respect of some life time distributions.
4. Computing Kaplan-Meier estimates based on recorded surviving times with and without censoring.
5. Fitting of Cox-Proportional Hazard Model.
6. Hypothesis Formulation and their Testing for Cox-Proportional Hazard Model.
7. Estimation of Mean Survival Time and its variance for complete and survival data.
8. Random union among gametes.
9. Gene effect on population mean.

Discipline Specific Elective (DSE) Course 1d: Official and National Development Statistics

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSE 1d: Official and National Development Statistics	**4**	**3**	**1**	**0**	**NIL**	**NIL**

Course Objectives:

- To provide the important information on Indian Official Statistical System.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Learn about the role and function of National and State Statistical Organizations.
- Knowing important sectors of Indian official statistics system (National and State) with their important regular publications.
- Understanding important data collection mechanism in different sectors.
- Finding important reasons for non-response while collecting Official Statistics.
- Learning concepts of National Accounts with the release.
- Finding statistics related to industries, foreign trade, balance of payment, cost of living, inflation, educational and other social statistics.
- Knowing socio-economic indicators, gender awareness/statistics, important surveys, and censuses pertaining to official statistics.

Unit I (11 Hours)

An overview of national and international statistical systems. National Statistical Organization: Vision and Mission, Central Statistical Office (CSO), National Sample Survey Office (NSSO); roles and responsibilities; important publications. Indian State statistical organizations: Important role, function and activities. Organization of large-scale sample surveys.

Unit II (12 Hours)

National Statistical Commission: Need, constitution, its role, functions, etc.; Legal acts/ provisions/support for Official Statistics. Data collection & compilation mechanism, processing, analysis and dissemination systems, agencies involved. Population growth in developed and developing countries, evaluation and performance of family welfare programmes.

Unit III (10 Hours)

Scope and content of population census of India, method of data collection. Sector wise statistics: Agriculture, Environment and Forestry, Health, Education, Women, and Child, etc. Important surveys & censuses, indicators, agencies, and usages, etc.

Unit IV (12 Hours)

National Accounts: Definition, basic concepts, issues, the strategy, collection of data and release. System of collection of agricultural and forestry statistics, crop forecasting and estimation, productivity, fragmentation of holdings, support prices. Statistics related to industries, foreign trade, balance of payment, cost of living, inflation, educational and other social statistics. Socio-Economic Indicators, Gender Awareness/Statistics.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Ministry of Statistics and Programme Implementation (MoSPI). Statistical System in India. Government of India.
2. Saluja, M.R. (2017). *Measuring India. The Nation's Statistics System*, OUP Catalogue, Oxford University Press.

Suggested Readings:

1. Directorate General of Commercial Intelligence and Statistics (DGCIS). Monthly Statistics of the Foreign Trade of India. Calcutta: DGCIS.
2. Forest Survey of India (2023). India State of Forest Report. Dehradun: Forest Survey of India.
3. Ministry of Agriculture and Farmer's Welfare, Government of India. Pocket Book of Agricultural Statistics.
4. Panse, V.G. (1954). *Estimation of Crop Yields. Food and Agricultural Organization.*
5. Reserve Bank of India. Handbook of Statistics on the Indian Economy. Mumbai: Reserve Bank of India
6. UNESCO. Principles and recommendations for population and housing censuses. Revision 3. New York: United Nations.

Generic Elective (GE) Courses

Generic Elective (GE) Course 1a: Statistical Computing Using R

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (00 Hours)	Practical (30 Hours)		
GE 1a: Statistical Computing Using R	**4**	**3**	**0**	**1**	**NIL**	**NIL**

Course Objectives:

- To learn the principles and methods of data analysis.
- To provide a basic understanding of methods of analysing data from different fields.
- To perform data analysis using R software.

Course Learning Outcomes: After successful completion of this course, the students will be able to:

- Carry out data analysis using R software.
- Effectively visualize and summarize the data.
- Interpret the results of statistical analysis.

Unit I (11 Hours)

Introduction to R: Installing R, R console, Script file, Workspace, Getting help, R packages, Installing and loading packages. R data structures: vectors, matrices, array, data frames, factors, lists. Creating datasets in R, Importing and exporting dataset, annotating datasets. Graphs: Creating and saving graphs, customizing symbols, lines, colors and axes, combining multiple graphs into one, bar plots, boxplot and dot plots, pie chart, stem and leaf display, histogram and kernel density plots. Data management: Manipulating dates and missing values, understanding data type conversion, creating and recoding variables, sorting, merging and sub-setting data sets. Mathematical and statistical functions, character functions, looping and conditional statements, user defined functions.

Unit II (11 Hours)

Basic statistics: Descriptive statistics, frequency and contingency tables, outlier detection, testing of normality, basics of statistical inference in order to understand hypothesis testing, p-value and confidence intervals. Parametric tests: Tests for population mean and variance for two or more populations, tests for independence and measures of association, sample size determination for common statistical methods using pwr package. Nonparametric tests.

Unit III (11 Hours)

Correlation: Correlations between quantitative variables and their associated significance tests. Regression Analysis: Fitting simple and multiple regression model forward, backward and stepwise regression, polynomial regression, regression diagnostics to assess the statistical assumptions, methods for modifying the data to meet these assumptions more closely, selecting a final regression model from many competing models. ANOVA: Fitting and interpreting ANOVA type models, evaluating model assumptions, basic experimental designs: CRD, RBD, LSD and factorial experimental designs.

Unit IV (12 Hours)

Time series Analysis: Creating and manipulating a time series, Components of a time series, auto-correlation and partial correlation function, estimating and eliminating the deterministic components of a time series. Developing Predictive Models: Forecasting using exponential models, predictive accuracy measures for time-series forecast, testing for stationarity, Forecasting using ARMA and ARIMA models. EM algorithm: Applications to missing and incomplete data problems, mixture models.

Essential Readings:

1. Davies, T.M. (2016). *The Book of R: A First Course in Programming and Statistics*, No Starch Press.
2. Field, A., Miles, J. and Field, Z. (2012). *Discovering Statistics using R*, Sage.

Suggested Readings:

1. Crawley, M.J. (2013). *The R Book*, John Wiley & Sons.
2. Kabacoff, R.I. (2015). *R in Action: Data Analysis and Graphics in R*, Manning Publications.
3. Rizzo, M.L. (2019). *Statistical Computing with R*, Chapman & Hall/CRC Press.

List of Practicals:

1. Problems based on creating vectors and mathematical operations.
2. Problems based on sequences, replications, sorting and lengths.
3. To perform matrix operations, importing and exporting datasets.
4. Basic plotting of R graphical functionality.
5. Basic statistics and testing of hypothesis.
6. Parametric and non-parametric tests.
7. Problems based on sample size determination.
8. Correlation and regression analysis using quantitative variables.
9. Analysis of variance and basic design of experiments (CRD, RBD, LSD and factorial designs).
10. To plot a time series function, autocorrelation function and correlogram.
11. Problems based on ARMA and ARIMA models.
12. Problems based on EM algorithms for missing and incomplete data problems.

Skill Based/Specialized Laboratory (SB) Course

Skill Based/Specialized Laboratory (SB) Course 1a: Data Analysis Using Excel

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (00 Hours)	Tutorial (00 Hours)	Practical (60 Hours)		
SB 1a: Data Analysis Using Excel	2	0	0	2	NIL	NIL

Course Objectives

- To provide students with a solid understanding of fundamental statistical concepts and practical experience in using Microsoft Excel for data analysis.
- To develop ability in students to be proficient in applying statistical techniques to interpret data and make decisions using Excel tools.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Grasp fundamental statistical concepts and their real world applications.
- Conduct both descriptive and inferential statistical analyses using Excel functions and tools.
- Analyze, interpret and effectively present statistical findings.

Unit 1 (15 Hours)

Introduction to MS Excel: Interface, functions, and statistical functions, data analysis ToolPak for statistical analysis, descriptive statistics, basic matrix operations, addition, multiplication, transpose, determinant, inverse, eigenvalues and eigenvectors, problem solving using Excel functions for sampling techniques, including simple random sampling, stratified random sampling, systematic sampling, ratio and regression estimation, cluster sampling and two-stage sampling methods.

Unit 2 (15 Hours)

Hypothesis testing using Excel- z-test for single mean, difference of two means and related confidence intervals, t-test for single mean, difference of two means, paired t-test and related confidence intervals, t-test for correlation coefficient.

Unit 3 (15 Hours)

Hypothesis testing using Excel- chi-square test for single variance, chi-square test for independence of attributes, chi-square test for testing goodness of fit, Bartlett's test, F-test for difference of two variances and related confidence intervals.

Unit 4 (15 Hours)

Advanced problem-solving using Excel functions and the data analysis ToolPak for One and two-Way ANOVA, completely randomized design (CRD), randomized block design (RBD), Latin square design (LSD) and analysis of RBD and LSD with missing observations.

Essential Readings:

1. Kronthaler, F. (2022). *Statistics Applied with Excel: Data Analysis Is (Not) an Art.* Springer
2. Kanji, G.K. (2006). *100 Statistical Tests*, SAGE Publications.
3. Montgomery, D.C. (2013). *Design and Analysis of Experiments*, John Wiley & Sons.
4. Rajagopalan, V. (2006). *Selected Statistical Tests*, New Age International Publishers, New Delhi.

Suggested Readings:

1. Panneerselvam, R. (2024). *Business Statistics Using Excel: A Complete Course in Data Analytics*, Routledge.
2. Schmuller, J. (2009). *Statistical Analysis with Excel for Dummies*, Wiley.
3. Searle, S.R., & Khuri, A.I. (2017). *Matrix Algebra Useful for Statistics*, John Wiley & Sons.

Semester II

Discipline Specific Core (DSC) Courses

Discipline Specific Core (DSC) Course 2a: Statistical Inference

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSC 2a: Statistical Inference	4	3	1	0	NIL	NIL

Course Objectives:

- To make students aware of estimation (both point and interval) and testing (both simple and composite hypotheses) procedures.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Apply various estimation and hypothesis testing procedures to deal with real life problems.
- Demonstrate a comprehensive understanding of Fisher Information, Lower bounds to variance of estimators, Minimum Variance Unbiased Estimator (MVUE).
- Explain and apply the Neyman-Pearson fundamental lemma, develop UMP tests and perform interval estimation, including the construction of confidence intervals.

Unit I (12 Hours)

Minimal sufficiency and ancillarity, Exponential families and Pitman families, Invariance property of Sufficiency under one-one transformations of sample and parameter spaces. Fisher Information for one and several parameters models. Lower bounds to variance of estimators for one and several parameters models, necessary and sufficient conditions for MVUE.

Unit II (12 Hours)

Neyman-Pearson fundamental lemma and its applications, UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family. Extension of these results to Pitman family when only upper or lower end depends on the parameters and to distributions with MLR property.

Unit III (10 Hours)

Non-existence of UMP tests for simple null against two-sided alternatives in one parameter exponential family. Families of distributions with monotone likelihood ratio and UMP tests.

Unit IV (11 Hours)

Interval estimation, confidence level, construction of shortest expected length confidence interval, uniformly most accurate one-sided confidence Interval and its relation to UMP tests for one-sided null against one-sided alternative hypotheses.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Bartoszynski, R. and Bugaj, M.N. (2007). *Probability and Statistical Inference*, John Wiley & Sons.
2. Casella, G. and Berger, R.L. (2013). *Statistical Inference*, Cengage Learning.
3. Kale, B.K. (1999). *A First Course on Parametric Inference*, Narosa Publishing House.
4. Rohatgi, V.K. and Saleh, A.K.Md.E. (2005). *An Introduction to Probability and Statistics*, John Wiley & Sons.

Suggested Readings:

1. Ferguson, T.S. (1967). Mathematical Statistics, Academic Press.
2. Lehmann, E.L. (1986). *Testing Statistical Hypotheses*, John Wiley & Sons.
3. Lehmann, E.L. (1986). *Theory of Point Estimation*, John Wiley & Sons.
4. Rao, C.R. (1973). *Linear Statistical Inference and Its Applications*, Wiley Eastern Ltd.
5. Zacks, S. (1971). *Theory of Statistical Inference*, John Wiley & Sons.

Discipline Specific Core (DSC) Course 2b: Design of Experiments

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSC 2b: Design of Experiments	4	3	1	0	NIL	NIL

Course Objectives:

- To provide students ability to formulate the design and conduct experiments, as well as to analyze and interpret data.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Apply ANOVA for two –way classification, fixed effect models with equal, unequal and proportional number of observations per cell, Random and Mixed effect models with m (>1) observations per cell.
- Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance.
- Understand the concepts of finite fields and finite geometries and apply them in construction of MOLS, construction of balanced incomplete block designs, confounded factorial experiments.
- Identify the effects of different factors and their interactions and analyse factorial experiments.
- Construct complete and partially confounded factorial designs and perform their analysis.
- Apply Split-plot designs and their analysis in practical situations.
- Understand the effects of independence or dependence of different factor under study.

Unit I (12 Hours)

Review of linear estimation and basic designs. Elimination of heterogeneity in two directions. ANOVA: Fixed effect models (2-way classification with equal, unequal and proportional number of observations per cell), Random and Mixed effect models (2-way classification with m (>1) observations per cell).

Unit II (12 Hours)

Incomplete Block Designs. Concepts of Connectedness, Orthogonality and Balance.

Intrablock analysis of Generic Incomplete Block design. B.I.B designs with and without recovery of interblock information.

Unit III (11 Hours)

Finite fields. Finite Geometries- Projective geometry and Euclidean geometry. Construction of complete set of mutually orthogonal latin squares. Construction of B.I.B.D. using finite Abelian groups, MOLS, finite geometry and method of differences.

Unit IV (10 Hours)

Symmetrical factorial experiments (sm, where s is a prime or a prime power), Confounding in sm factorial experiments through pencils, sk-p fractional factorial where s is a prime or a prime power. Split-plot experiments.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Chakrabarti, M.C. (1962). *Mathematics of Design and Analysis of Experiments*, Asia Publishing House.
2. Dey, A. (1986). *Theory of Block Designs*, John Wiley & Sons.
3. Nigam, A.K. Puri, P.D. and Gupta, V.K. (1988). *Characterizations and Analysis of Block Designs*, John Wiley & Sons.
4. Raghavarao, D. (1970). *Construction and Combinatorial Problems in Design of Experiments*, John Wiley & Sons.

Suggested Readings:

1. Das, M.N. and Giri, N.C. (1986). *Design and Analysis of Experiments*, John Wiley & Sons.
2. Dean, A. and Voss, D. (1999). *Design and Analysis of Experiments*, Springer.
3. Dey, A. (2010). *Incomplete Block Designs*, World Scientific.
4. Hinkelmann, K. and Kempthorne, O. (2005). *Design and Analysis of Experiments*, John Wiley & Sons.
5. John, P.W.M. (1971). *Statistical Design and Analysis of Experiments*, Macmillan Publishing Co.
6. Kshirsagar, A.M. (1983). *A Course in Linear Models*, Marcel Dekker, Inc.
7. Montgomery, D.C. (2005). *Design and Analysis of Experiments*, John Wiley & Sons.
8. Raghavarao, D. and Padgett, L.V. (2005). *Block Designs: Analysis, Combinatorics, and Applications*, World Scientific.

Discipline Specific Core (DSC) Course 2b: Stochastic Processes

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSC 2b: Stochastic Processes	4	3	1	0	NIL	NIL

Course objectives:

- To develop awareness for the use of stochastic models for representing random phenomena evolving in time such as inventory or queueing situations or stock prices behavior

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Use notions of long-time behaviour including transience, recurrence, and equilibrium in applied situations such as branching processes and random walk.
- Construct transition matrices for Markov dependent behaviour and summarize process information
- Use selected statistical distributions for modeling various phenomena.
- Understand the principles and objectives of model building based on Markov chains, Poisson processes and Brownian motion.

Unit I (12 Hours)

Review of Basic Probability Concepts. Introduction to Stochastic Processes. Deterministic and Stochastic Exponential Growth Models. Stationary and Evolutionary Processes. Poisson Processes: Poisson distribution and Poisson Process. Arrival, Interarrival and Conditional Arrival Distributions. Nonhomogeneous Processes. Law of Rare Events and Poisson Process. Poisson Point Process. Distributions associated with Poisson Process. Compound Poisson Processes.

Unit II (12 Hours)

Markov Chains: Transition Probability Matrices, Chapman- Kolmogorov equations, Some Examples and Classification of States, Regular Chains and Stationary Distributions, Periodicity, Limit theorems. Some Applications. Patterns for recurrent events: One-dimensional, two-dimensional and three-dimensional random walks.

Unit III (11 Hours)

Brownian Motion: Limit of Random Walk, Its Defining Characteristics and Peculiarities. Its Variations: Standard Brownian Motion, Brownian Bridge, Brownian Motion Reflected at Origin, Geometric Brownian Motion, Brownian Motion with Drift. Reflection Principle. Some Applications.

Unit IV (10 Hours)

Renewal Processes: Preliminaries, Elementary Renewal Theorem, Delayed Renewal Processes. Limit Theorems. Martingales: Definitions and Some Examples, Stopping Times, Martingale Stopping Theorem, Wald Equation.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Medhi, J. (2009). *Stochastic Processes*, New Academic Science.
2. Ross, S.M. (1996). *Stochastic Processes*, John Wiley & Sons.
3. Taylor, H.M. and Karlin, S. (1998). An Introduction to Stochastic *Modelling*, Academic Press.

Suggested Readings:

1. Bhat, B.R. (2000). *Stochastic Models-Analysis and Applications*, New Age International Publishers.
2. Feller, William (1968). *An Introduction to Probability Theory and its Applications*, Vol. 1, John Wiley & Sons.
3. Karlin, S. and Taylor, H.M. (1975). *A first course in Stochastic Processes*, Academic Press.
4. Prabhu, N.U. (2007). *Stochastic Processes: Basic Theory and its Applications*, World Scientific.

Discipline Specific Elective (DSE) Courses

Discipline Specific Elective (DSE) Course 2a: Linear Algebra

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSE 2a: Linear Algebra	4	3	1	0	NIL	NIL

Course Objectives:

- To allow students to manipulate and understand multidimensional space.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Demonstrate a deep understanding of vector spaces, subspaces, linear independence, basis, and dimension.
- Analyze and interpret linear transformations, matrix representations, and change of basis, including orthogonality and inner product spaces.
- Apply orthogonality and the Gram-Schmidt process in practical problems.
- Compute eigenvalues, eigenvectors, and perform spectral and decomposition.
- Use generalized inverses and quadratic forms in practical problems.

Unit I (10 Hours)

Concept of groups and fields with examples, Vector spaces and Subspaces with examples, Direct sum and Algebra of subspaces viz. sum, intersection, union etc, Linear combinations, Spanning sets, Linear spans, Linear dependence and independence in vector spaces, Row and Column space of a matrix, Basis and Dimensions.

Unit II (11 Hours)

Linear Transformations, Kernel and Image of a linear transformation, Rank and Nullity, Matrix representation of a linear operator, Change of Basis, Similarity, Inner product spaces with examples, Cauchy-Schwarz inequality with applications, Orthogonality, Orthonormal sets and Bases, Gram Schmidt Orthogonalization Process.

Unit III (12 Hours)

Eigenvalues and eigenvectors, Spectral decomposition of a symmetrical matrix (Full rank and non-full rank cases), Example of spectral decomposition, Spectral decomposition of asymmetric matrix, Cayley Hamilton theorem, Algebraic and geometric multiplicity of characteristic roots, Diagonalization of matrices, Factorization of a matrix, Eigenvalues and eigenvectors for solution of Differential equations.

Unit IV (12 Hours)

Generalized inverse of a matrix, Different classes of Generic ized inverse, Properties of g-inverse, Reflexive g-inverse, left Weak and right Weak g-inverse, Moore- Penrose (MP) g-inverse and its properties, Real quadratic form, Linear transformation of quadratic forms, Index and signature, Reduction of quadratic form into sum of squares, Gram matrix with example, Jordan canonical form.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Axler, S. (2024). *Linear Algebra Done Right*, Springer.
2. Searle, S.R. and Khuri, A.I. (2017). *Matrix algebra useful for statistics*. John Wiley & Sons.
3. Strang, G. (2012). *Linear Algebra and its Applications*, Academic Press.

Suggested Readings:

1. Biswas, S. (1997). *A Text Book of Matrix Algebra*, New Age International Publishers.
2. Golub, G.H. and Van Loan, C.F. (1989). *Matrix Computations,* John Hopkins University Press.
3. Hadley, G. (2002). *Linear Algebra,* Narosa Publishing House.
4. Rao, C.R. (1973). *Linear Statistical Inferences and its Applications*, John Wiley & Sons.
5. Robinson, D.J.S. (1991). *A Course in Linear Algebra with Applications*, World Scientific.

Discipline Specific Elective (DSE) Course 2b: Non-Parametric Inference

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (00 Hours)	Practical (30 Hours)		
DSE 2b: Non-Parametric Inference	**4**	**3**	**0**	**1**	**NIL**	**NIL**

Course Objectives:

- Develop the ability to learn the fundamentals of the most relevant nonparametric techniques for statistical inference.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Solve hypothesis testing problems where the conditions for the traditional parametric inferential tools to be applied are not fulfilled.
- Build nonparametric density estimates.

Unit I (11 Hours)

Review of order statistics, Distribution-free statistics over a class, counting statistics, ranking statistics, Statistics utilizing counting and ranking, One sample and two sample U-statistics, Asymptotic distribution of U-statistics, point estimation. Estimators associated with distribution free test statistics, Exact small-sample and asymptotic properties of the Hodges-Lehmann location estimators.

Unit II (11 Hours)

Tests based on length of the longest run, runs up and down, Kolmogorov-Smirnov two sample statistic. Rank order statistics: Correlation between ranks and variate values, One sample, paired sample and two sample problems, Linear rank tests, distribution properties of linear rank statistics.

Unit III (11 Hours)

Tests for equality of k independent samples: Kruskal-Wallis one way ANOVA test, Measures of Association for bivariate samples: Kendall's Tau coefficient, Spearman's coefficient of Rank correlation, relations between R and T; E (R), τ and ρ.

Unit IV (12 Hours)

Measures of association in multiple classifications: Friedman's two-way ANOVA by ranks in a k x n table, the Coefficient of Concordance of k sets of rankings of n objects, the Coefficient of Concordance of k sets of incomplete rankings, Kendall's Tau coefficient for partial correlation.

Essential Readings:

1. Gibbons, J.D. and Chakraborti, S. (2021). *Nonparametric Statistical Inference*, CRC Press.
2. Hettmansperger, T.P. (1984). *Statistical inference Based on Ranks*, John Wiley & Sons.
3. Randles, R.H. and Wolfe, D.A. (1979). *Introduction to the Theory of Nonparametric Statistics*, John Wiley & Sons.

Suggested Readings

1. David, H.A. and Nagaraja, H.N. (2003). *Order Statistics*, John Wiley & Sons.
2. Rohatgi, V.K. and Saleh, A.K.Md.E. (2005). *An Introduction to Probability and Statistics*, John Wiley & Sons.
3. Siegel, S. and John, J.S.N. (2010). *Nonparametric Statistics for the Behavioral Sciences*, McGraw-Hill

List of Practicals:

1. Point estimation. Estimators associated with distribution free test statistics.
2. Kolmogorov-Smirnov one and two sample statistic.
3. Correlation between ranks and variate values
4. One sample, paired sample and two sample problems.
5. Kruskal-Wallis one way ANOVA test.
6. Kendall's Tau coefficient.
7. Spearman's coefficient of Rank correlation, relations between R and T; E (R), τ and τ.
8. Friedman's two-way ANOVA by ranks in a k x n table.
9. Coefficient of Concordance of k sets of rankings of n objects.
10. Coefficient of Concordance of k sets of incomplete rankings.

Discipline Specific Elective (DSE) Course 2c: Statistical Quality Control

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (00 Hours)	Practical (30 Hours)		
DSE 2c: Statistical Quality Control	**4**	**3**	**0**	**1**	**NIL**	**NIL**

Course Objectives:

- To introduce the most important field of applied statistics that contributes to quality control in almost all industries.

Course Learning Outcomes: After successful completion of this course, student will be able to:

- Describe the DMAIC process (define, measure, analyze, improve, and control).
- Demonstrate to use the methods of statistical process control and to determine when an out-of-control situation has occurred.
- Design and use Cumulative sum chart, tabular Cumulative sum chart and V-mask schemes for detecting small shifts of the mean from goal conditions.
- Choose an appropriate sampling inspection technique.
- Gain the ability to understand the concept of errors in making inference
- Understand the concept of OC and ARL of control chart.
- Understand the concept of Dodge's continuous sampling inspection plans.

Unit I (11 Hours)

Basic concepts of process monitoring and process control, Generic theory and review of attributes and variable control charts, errors in making inferences from control charts, OC and ARL of control charts.

Unit II (11 Hours)

Moving average and exponentially weighted moving average control chart (EWMA), cumulative sum control chart (CUSUM) using V-mask and decision intervals, economic design of $\overline{X}$ Chart.

Unit III (12 Hours)

Methods and philosophy of statistical process control, process and measurement system capability analysis: process capability ratios, process capability analysis using a control chart, gauge and measurement system capability studies.

Unit IV (11 Hours)

Review of sampling inspection techniques, single sampling plans, double sampling plans, multiple sampling plans, sequential sampling plans and their properties, Dodge's continuous sampling inspection plans for inspection by variables for one-sided and two-sided specifications.

Essential Readings:

1. Levinson, W.A. (2010). *Statistical Process Control for Real-World Applications*, CRC Press.
2. Montgomery, D.C. (2019). *Introduction to Statistical Quality Control*, John Wiley & Sons.
3. Wetherill, G.B. (1977). *Sampling Inspection and Quality Control*, Halsted Press.

Suggested Readings:

1. Biswas, S. (1996). *Statistics of Quality Control, Sampling Inspection and Reliability*, New Age International Publishers.
2. Burr, I.W. (2020). *Statistical Quality Control Methods*: 16 (Statistics: A Series of Textbooks and Monographs), CRC Press.
3. Dale, B.H., Carol, B., Glen, B.H., Hemant, B.U. (2018). *Total Quality Management*, Pearson.
4. Duncan A.J. (1974). *Quality Control and Industrial Statistics*, Taraporewala & Sons.
5. Grant, E.L. and Leavenworth, R.S. (2017). *Statistical Quality Control*, McGraw Hill.
6. Knoth S. and Schmid W. (2021). *Frontiers in Statistical Quality Control*, Springer.
7. Mittag, H. J., and Rinne, H. (1993). *Statistical Methods of Quality Assurance*, Chapman & Hall.
8. Montgomery, D.C. (2010). *Statistical Quality Control: A Modern Introduction*, John Wiley & Sons.
9. Ott, E.R. (2005). *Process Quality Control: Troubleshooting And Interpretation of Data Standards media*, 4th edition.
10. Wetherill, G.B. Brown, D.W. (1991). *Statistical Process Control Theory and Practice*, Chapman & Hall.

List of Practicals:

1. Control charts for mean and range
2. Control charts for mean and standard deviation
3. Control charts for individual units
4. Lot-by-lot attribute sampling plans
5. Cumulative sum control chart
6. Moving average control chart
7. Exponentially weighted moving average control chart
8. Process capability analysis procedure.

Discipline Specific Elective (DSE) Course 2d: Reliability Theory

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical (00 Hours)		
DSE 2d: Reliability Theory	4	3	1	0	NIL	NIL

Course Objectives:

- Introduces fundamental reliability concepts, including reliability, availability, and maintainability, and explores their interrelationships.
- Define reliability and explain its significance in engineering and systems.
- Learn key reliability measures such as failure rate, mean time to failure (MTTF), and mean time between failures (MTBF).
- Understand redundancy techniques and their applications in improving system reliability.
- Understand new better than used (NBU), decreasing mean residual life (DMRL), and new better than used in expectation (NBUE) properties.

Course Learning Outcomes:

- To analyze the system reliability, including coherent systems and their reliability estimation.
- Investigate reliability in systems with imperfect switches and priority redundant systems.
- Explain the loss of memory property of the exponential distribution and its significance in failure modeling.
- Apply Markov models to reliability function analysis and use regenerative point techniques to analyze system reliability.

Unit I (12 Hours)

Reliability concepts & measures, components and systems, coherent system, reliability of the coherent system. Availability, types of availability- point wise, interval, asymptotic. Failure rate and mean time to failure and their inter-relationships. Statistical failure models: exponential. gamma, Weibull, Pareto, normal, lognormal and related distributions.

Unit II (10 Hours)

System components and configurations: series-parallel, parallel-series, and K-out of –N-system. Series- strength reliability and its estimation. Reliability Bounds- classical and Bayesian approach.

Unit III (11 Hours)

Maintenance Policies, System with imperfect switch. Concept of redundancy, types of redundancy, priority redundant, repairable system, comparison of component, unit and standby redundancies.

Unit IV (12 Hours)

Model Plotting techniques: Reliability function with Markov model. Two unit cold standby & parallel unit system with constant failure rate, Arbitrary Repair rates & Regenerative point Techniques. Stress strength reliability and its estimation. IFR, IFRA, NBU, DMRL and NBUE and their duals, loss of memory property of the exponential distribution.

Tutorial:

Tutorial sessions will include at least one activity such as group discussion/presentation/ problem solving exercise based on the material covered in the lectures along with scholastic work related to the conceptual understanding of the subject.

Essential Readings:

1. Balagurusamy, E. (2017). *Reliability Engineering*, McGraw Hill.
2. Bazovsky, I. (2013). *Reliability Theory and Practice*, Dover Publications.
3. Billinton, R. and Allan, R.N. (2013). *Reliability Evaluation of Engineering Systems: Concepts and Techniques*, Springer.
4. Cooper, R.B. (1981). *Introduction to Queuing Theory*, Elsevier.
5. Cox, D.R., and Miller, H.D. (1972). *The Theory of Stochastic Processes*, Chapman & Hall.

Suggested Readings:

1. Gross, D. and Harris C.M. (2008). *Fundamentals of Queueing Theory*, John Wiley & Sons.
2. Lewis, E.E. (1996). *Introduction to Reliability Engineering*, John Wiley & Sons.
3. Medhi, J. (2022). *Stochastic processes,* New Age International Publications.
4. Meeker, W.Q. and Escobar, L.A. (1998). *Statistical Methods for Reliability Data*, John Wiley & Sons.
5. Satty, T.L. (1983). *Elements of Queuing Theory with Applications*, Dover Publications.

Discipline Specific Elective (DSE) Course 2e: Computational Techniques

Course Title and Code	Credits	Credit Distribution of Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (30 Hours)	Tutorial (00 Hours)	Practical (60 Hours)		
DSE 1a: Computational Techniques	4	2	0	2	NIL	NIL

Course Objectives:

- To learn the advanced techniques of modelling real data from diverse discipline.

Course Learning Outcomes: After successful completion of this course, the students will be able to:

- Simulate statistical models.
- Understand linear models and distinguish between fixed, random and mixed effects models.
- Learn and apply regression technique in their area of study.
- Understand and apply time series models.

Unit I (7 Hours)

Probability Distributions: Bernoulli, Binomial, Poisson, Multinomial, Uniform, Exponential, Gamma, Beta, Normal, Chi Square, t and F distribution. Simulation: Random number generation, simulating statistical models, Monte Carlo Methods.

Unit II (8 Hours)

Linear Models: Fixed, random and mixed effects models, ANOVA: one way and two-way, ANOCOVA. Regression Models: Simple and Multiple Linear Regression, Forward, Backward and stepwise regression, Residual analysis. Diagnostics and tests for violations of model assumptions: Multicollinearity, Autocorrelation and Homoscedasticity.

Unit III (7 Hours)

Generalized Linear Model: Exponential family of distributions, Link function, Canonical link Function, deviance, Logit and Probit models, Logistic and Poisson regression. Lack of fit tests.

Unit IV (8 Hours)

Time Series: Stationary and Nonstationary time series, Autocorrelation and Auto-covariance functions and their properties, Tests for trend and seasonality. Stationary processes: Moving average (MA) process, Auto-regressive (AR) process, ARMA, ARIMA and SARIMA models. Estimation of mean, auto-covariance and auto-correlation function under large sample theory, forecasting.

Note: Data analysis and applications of the methods are to be carried out using a statistical package like Excel/R/SPSS/MINITAB/MATLAB or any other.

Essential Readings:

1. Agresti, A. (2015). *Foundations of Linear and Generalized Linear Models,* John Wiley & Sons.
2. Chatterjee, S. and Hadi, A.S. (2012). *Regression Analysis by Example,* John Wiley & Sons.
3. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). *Discrete Univariate Distributions,* John Wiley & Sons.
4. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). *Continuous Univariate Distributions,* John Wiley & Sons.
5. Montgomery, D.C. (2001). *Designs and Analysis of Experiments*, John Wiley & Sons.
6. Montgomery, D.C., Jennings, C.L. and Kulahci, M. (2008). *Introduction to Time Series Analysis and Forecasting,* John Wiley & Sons.
7. Ross, S.M. (2006). *Simulation,* American Press.

Suggested Readings:

1. Cryer, J.D. and Chan, K. (2008). *Time Series Analysis: With Applications in R,* Springer.
2. Fox, J. and Weisberg, S. (2011). *An R Companion to Applied Regression,* Sage.
3. Kroese, D.P. and Chan, J.C.C. (2014). *Statistical Modeling and Computation,* Springer.
8. Voss, J. (2014). *An Introduction to Statistical Computing,* John Wiley & Sons.
9. Weisberg, S. (2014). *Applied Linear Regression,* John Wiley & Sons.

List of Practicals:

1. Fitting of Probability distributions.
2. Random number generation
3. Problem based on one way ANOVA and Two-way ANOVA
4. Problem based on ANOCOVA

5. Fitting of Linear Regression, Forward, Backward and stepwise regression.
6. Logistic and Poisson regression. Lack of fit tests.
7. Time Series: Tests for trend and seasonality.
8. Fitting and forecasting of various time series processes: MA, AR, ARMA, ARIMA, SARIMA.

Generic Elective (GE) Courses

Generic Elective (GE) Course 2a: Statistics for Research and Management Studies

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (30 Hours)	Tutorial (00 Hours)	Practical (60 Hours)		
GE 2a: Statistics for Research and Management Studies	**4**	**2**	**0**	**2**	**NIL**	**NIL**

Course Objectives:

- To learn statistical techniques useful for research work.
- To understand the quantitative methods used in business and management studies.

Course Learning Outcomes: After successful completion of this course, the students will be able to:

- Know different types of data produced in their area of study.
- Create, manage, visualize, and summarize datasets.
- Use and understand the inferential procedures.
- Apply suitable sampling design.
- Understand and apply basic designs.
- Apply regression techniques.
- Apply suitable statistical techniques to analyze the data and interpret the results.

Unit I (7 Hours)

Data types, scale of measurement, creating and managing datasets, importing and exporting data, data cleaning. Summarizing data: Frequency and probability distributions, measures of central tendency, measures of dispersion, skewness and kurtosis. Correlation and regression, Measures of association, Cross tabulation. Visualizing data: Histogram, bar chart, pie chart, stem and leaf display, scatter plot, box and whisker plot.

Unit II (8 Hours)

Inference: Population and sample, parameter and statistic, estimates and estimators, estimation of parameters, testing of hypothesis, type I and type II errors, p-value, inferences based on sample. Tests based on sampling distributions: Z, t, χ^2 and F.

Unit III (8 Hours)

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling, basic principles of sample survey, Sampling Techniques: Simple random sampling, stratified random sampling, Cluster Sampling, Systematic sampling.

Unit IV (7 Hours)

ANOVA for one way and two-way classification. ANCOVA, analysis of basic designs, analysis of 2 level factorial experiments. Simple and multiple regression, logistic regression.

Note: Data analysis and applications of the methods are to be carried out using calculator or by using a statistical package like Excel/R.

Essential Readings:

1. Cochran, W.G. (2011). *Sampling Techniques*, John Wiley & Sons.
2. Judd, C.M., McClelland, G.H. and Ryan, C.S. (2009). *Data Analysis: A Model Comparison Approach*, Routledge.
3. Montgomery, D.C. (2001). *Design and Analysis of Experiments*, John Wiley.

Suggested Readings:

1. Agresti, A. (2015). *Foundations of linear and generalized linear models*. John Wiley & Sons.
2. DeGroot, M.H. and Schervish, M.J. (2012). *Probability and Statistics*, Pearson.
3. Field, A., Miles, J. and Field, Z. (2012). *Discovering Statistics Using R*, Sage.
4. Rao R.D. (1988). *Exploring Statistics,* Markel Dekker.
5. Rice, J.A. (1995). *Mathematical Statistics and Data Analysis*, Duxbury Press.
6. Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Asok, C. (1984). *Sampling Theories of Survey with Application*, IOWA State University Press and Indian Society of Agricultural Statistics.
7. Taylor, J.K. and Cihon, C. (2004). *Statistical Techniques for Data Analysis*, Chapman & Hall.

List of Practicals:

1. Measures of central tendency, measures of dispersion, skewness and kurtosis.
2. Correlation and regression, measures of association, cross tabulation.
3. One-way ANOVA and two-way ANOVA and ANOCOVA.
4. Histogram, bar chart, pie chart, stem and leaf display, scatter plot, box and whisker plot
5. Testing of hypothesis.
6. Different sampling techniques as per syllabus.
7. Tests based on sampling distributions: Z, t, χ^2 and F.

Skill Based/Specialized Laboratory (SB) Courses

Skill Based/Specialized Laboratory Course 2a: Data Analysis Using Python

Course Title & Code	Credits	Credit Distribution of the Course			Eligibility Criteria	Prerequisite of the course (if any)
		Lecture (00 Hours)	Tutorial (00 Hours)	Practical (60 Hours)		
SB 2a: Data Analysis Using Python	2	0	0	2	NIL	NIL

Course Objective:

- To introduces Python as a tool for statistical analysis, covering data visualization, probability, statistical inference, regression, sampling, and matrix algebra.
- To develop understanding of fitting probability distributions, conducting hypothesis testing, and applying statistical models to real-world data using key Python libraries.

Course Learning Outcomes:

- Understand Python programming for statistical analysis.
- Develop computational skills for probability, inference, regression, and matrix algebra.
- Perform hypothesis testing, distribution fitting and ANOVA.
- Apply regression techniques and model selection for statistical analysis.

Software & Libraries Required:

1. Python (Jupyter Notebook / Google Colab).
2. Libraries: NumPy, Pandas, SciPy, Statsmodels, Seaborn, Matplotlib, Scikit-learn.

Unit 1 (15 Hours)

Python basics: Variables, loops, functions, list comprehensions, NumPy: One-dimensional & two-dimensional arrays, operations, Pandas: Data Frames, filtering, grouping, handling missing data, Data visualization: Histograms, boxplots, scatterplots, KDE plots, bar charts, pie charts, Probability distributions & simulations: Binomial, Poisson, Normal, Exponential, Monte Carlo methods, Law of Large Numbers & Central Limit Theorem.

Unit 2 (15 Hours)

Estimation: MLE, confidence intervals, bootstrapping, Hypothesis testing: Z-test, t-test, F-test, Wilcoxon signed-rank test, Kruskal-Wallis test, Analysis of variance (ANOVA): One-way, two-way, post-hoc tests (Tukey's HSD), Interpretation & visualization of hypothesis tests and ANOVA results.

Unit 3 (15 Hours)

Simple & multiple linear regression, assumptions, residual analysis and diagnostic plots, Model selection: Adjusted R^2, AIC, BIC, stepwise selection. Survey sampling: Simple random sampling, stratified sampling, estimation of population parameters. Handling missing data & graphical representation of survey results. Markov Chains: transition probability matrix, steady-state probabilities. Simulation of Markov Chains in Python.

Unit 4 (15 Hours)

Matrix operations: Addition, multiplication, inversion, eigenvalues, eigenvectors Spectral decomposition & solving linear systems. Fitting probability distributions using MLE & SciPy.stats Goodness-of-Fit Tests: Kolmogorov-Smirnov, Anderson-Darling, Chi-Square Visualization of fitted distributions using histograms & QQ-plots.

Essential Readings:

1. Balagurusamy, E. (2016). *Introduction to Computing and Problem-Solving Using Python*, McGraw Hill.
2. Halswanter, T. (2016). *An Introduction to Statistics with Python: With Applications in the Life Sciences*, Springer.

Suggested Readings:

1. McKinney, W. (2012). *Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython.* " O'Reilly Media, Inc.".
2. Perkovic, L. (2015). *Introduction to Computing Using Python: An Application Development Focus.* John Wiley & Sons.
3. Vander Plas, J. (2016). *Python Data Science Handbook: Essential Tools for Working with Data.* " O'Reilly Media, Inc.

DEPARTMENT OF STATISTICS
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UNIVERSITY OF DELHI, DELHI - 110007

M.A./M.Sc. (Statistics)

Curricular Structures of First year of Two year PG Programme (3+2)

Semester	Discipline Specific Core (DSC) Courses	Discipline Specific Elective (DSE) Courses	Generic Elective (GE) Courses	Skill Based (SB)/ Specialized Laboratory (SL) Courses
I	DSC 1a Probability Theory DSC 1b Statistical Methodology DSC 1c Survey Sampling	DSE 1a Analysis DSE 1b Time Series Analysis DSE 1c Biostatistics DSE 1d Official and National Development Statistics	GE 1a Statistical Computing Using R	SB 1a Data Analysis Using Excel
II	DSC 2a Statistical Inference DSC 2b Design of Experiments DSC 2c Stochastic Processes	DSE 2a Linear Algebra DSE 2b Non-Parametric Inference DSE 2c Statistical Quality Control DSE 2d Reliability Theory DSE 2e Computational Techniques	GE 2a Statistics for Research and Management Studies	SB 2a Data Analysis Using Python