UNIVERSITY OF DELHI

DEPARTMENT OF STATISTICS

1st year of 2-year PG Program under PGCF-Level 6

Proposed Syllabus
(Effective from AY 2025-26)

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.

		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:

In each semester 3 Core and either 2DSE or 1DSE+1GE 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	03	12	02	8	00	0	1	2	**22**
			01	4	01	4			
II	03	12	02	8	00	0	1	2	**22**
			01	4	01	4			
Total Credits for Ist Year of Two-Year Courses									**44**

Semester Wise Details:

Semester –I					
Discipline-Specific Core Courses: 3					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits
1a	Probability Theory	3	1	0	4
1b	Statistical Methodology	3	1	0	4
1c	Survey Sampling	3	0	1	4
Total credits		**9**	**2**	**1**	**12**

Discipline-Specific Elective (DSE) Courses:					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits

1a	Analysis	3	1	0	4
1b	Time Series Analysis	3	0	1	4
1c	Biostatistics	3	0	1	4
1d	Official and National Development Statistics	3	1	0	4
Total credits		**12**	**2**	**2**	**16**

Generic Elective (GE) Courses:					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits
1a	Statistical Computing using R	3	0	1	4
Total credits		**3**	**0**	**1**	**4**

Skill Based/Specialized Laboratory Courses:					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits
1a	Data Analysis using Excel	0	0	2	2
Total credits		**0**	**0**	**2**	**2**

Semester –II

Discipline-Specific Core (DSC) Core Courses: 3					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits
2a	Statistical Inference	3	1	0	4
2b	Design of Experiments	3	0	1	4
2c	Stochastic Processes	3	1	0	4
Total credits		**9**	**2**	**1**	**12**

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

Total credits	**14**	**2**	**4**	**20**

Generic Elective (GE) Courses:					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits
2a	Statistics for Research and Management Studies	2	0	2	4
Total credits		**2**	**0**	**2**	**4**

Skill Based/Specialized Laboratory Courses:					
Course code	**Course Title**	**Credits in each course**			
		Theory	Tutorial	Practical	Credits
1a	Data Analysis using Python	0	0	2	2
Total credits		**0**	**0**	**2**	**2**

First Year of Two-Year PG (M.A./ M.Sc. Statistics) Programme

Semester- I

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical/ Practice
DSC 1a: Probability Theory	4	3	1	0

Course Objectives: The aim of the course is to pay a special attention to applications of measure theory in the probability theory, understanding of Week 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:

1. Concepts of random variables, sigma-fields, probability distributions, and the independence of random variables related to measurable functions.
2. Skills in working with measurable functions and sequences of random variables.
3. The weak laws of large numbers in practical scenarios.
4. The strong laws of large numbers to solve real-world problems.
5. The central limit theorem in data analysis and interpretation.
6. Principles of convergence and modes of convergence to assess statistical data.
7. 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.

Suggested Readings:

1. Ash, R. B. and Doléans-Dade, C.A. (1999). Probability and Measure Theory, Second Edition, Academic Press, New York.
2. Bhat, B.R. (1999). Modern Probability Theory, 3rd Edition, New Age International Publishers.
3. Billingsley, P. (2012). Probability and Measure, Anniversery Edition, John Wiley & Sons.
4. Capinski, M. and Zastawniah (2001). Probability through problems, Springer.
5. Chung, K. L. (1974). A Course in Probability Theory, 2nd Edition, Academic Press, New York.

6. Feller, W. (1968). An Introduction to Probability Theory and its Applications, Vol. 1, 3rd Edition, John Wiley & Sons.
7. Parzen, E. (1960). Modern Probability Theory and its Application. Wiley Eastern Private Ltd.

Teaching Plan:

Week 1:	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.
Week 2:	Measure, Probability measure, properties of a measure, Caratheodory extension theorem (statement only), Lebesgue measures on R^K
Week 3:	Measurable functions, Random variables, sequence of random variables.
Week 4:	Integration of a measurable function with respect to a measure. Monotone convergence theorem.
Week 5:	Fatou's lemma, Dominated convergence theorem.
Week 6:	Characteristic functions, uniqueness/inversion/Levy continuity theorems.
Week 7:	Markov's, Chebychev's and Kolmogorov's inequalities. Modes of stochastic convergence. Jensen, Liapunov, Holder's and Minkowsky's inequalities.
Week 8:	Measurable functions, Random variables Sequence of random variables
Week 9:	Modes of convergence (convergence in distribution, in probability, almost surely, and quadratic mean) and their interrelations.
Week 10:	Statement of Slutsky's theorem. Borel –Cantelli lemma and Borel 0-1 law.
Week 11:	Concept of Independence, Laws of large numbers, Chebyshev's
Week 12:	Khinchine's WLLN, necessary and sufficient condition for the WLLN. Strong
Week 13:	Law of large numbers and Kolmogorov's theorem. Strong law of large numbers and Kolmogorov's theorem.
Week 14:	Central limit theorem, Lindeberg and Levy and Liapunov forms of CLT.

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical/ Practice
DSC 1b: Statistical Methodology	4	3	1	0

Course Objective: The aim of this course is 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:

1. 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.
2. Understand how to use non-central distributions in real life problems.
3. Understand different types of censoring schemes and their applications.
4. 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.

Suggested Readings:

1. Arnold, B.C., Balakrishnan, N., and Nagaraja, H.N. (1992). A First Course in Order Statistics, John Wiley & Sons.
2. Biswas, S. (1992). Topics in Statistical Methodology, Wiley-Blackwell.
3. David, H.A., and Nagaraja, H.N. (2003). Order Statistics, 3rd Edn., John Wiley & Sons.
4. Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, Wiley, International Students' Edition.
5. Huber, P.J. (1981). Robust Statistics, John Wiley & Sons.
6. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). Continuous Univariate Distributions, John Wiley & Sons.
7. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2000). Discrete Univariate John Wiley & Sons.
8. Mukhopadhyay, P. (2015). Mathematical Statistics. New Central Book Agency.
9. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, 2nd Edn., John Wiley & Sons.
10. Rohatgi, V.K. (1984). Statistical Inference, John Wiley & Sons.
11. Rohatgi, V.K. and Saleh, A. K. Md. E. (2005). An Introduction to Probability and Statistics, 2nd Edn., John Wiley & Sons.

Teaching Plan:

Week 1:	Concept of sample space, random variable, sigma field, minimal sigma field, probability measure, properties of probability density functions/probability mass functions and cumulative distribution functions, Concept of symmetric distributions.

Week 2:	Examples of discrete and continuous symmetric distributions, theorems based on symmetric distributions, Concept of truncated distributions, Examples of discrete and continuous truncated distributions, Concept of compound distributions, Examples of compound distributions.
Week 3:	Concept of Generalized power series distribution, moment generating function, Recurrence relation and cumulents of Generalized power series distribution, Particular cases of Generalized power series distribution.
Week 4:	Brief discussion of one parameter, two parameter and k-parameters exponential family of distributions. Particular cases of exponential family of distributions, Maximum likelihood estimation of exponential family of distributions and theorems based on exponential family of distributions.
Week 5:	Characterization properties and theorem of geometric distribution, Characterization properties of exponential distribution and related theorems, Characterization properties of normal distribution and related theorems. Characterization properties of gamma distribution.
Week 6:	Brief discussion of central Chi-square. Concept of Non-central Chi-square distribution, derivation of the probability density functions, characteristic functions, moment generating function, Cumulants and other theorems based on Non-central Chi-square distribution.
Week 7:	Brief discussion of t and F distributions. Concept of Non-central t and F distributions, derivation of their probability density functions, Derivation of r^{th} moment about origins of non-central t and F distributions. Derivation of mean and variance of non-central t and F distributions.
Week 8-9:	Discussion of Type I censoring, Type II censoring and Progressive censoring and problems based on these censoring schemes, Concept of Approximating distributions, First order, second order and higher order delta method. Problems based on delta method.
Week 10:	Approximating distributions of sample moments, Limiting moment generating function, Poisson approximation to negative binomial distribution, Concept of order statistics and problems/theorems based on order statistics.

Week 11:	Concept of tolerance intervals and problems based on tolerance intervals, Coverage of ($X_{(r)}$, $X_{(s)}$), Generic theory of linear and multiple regression.
Week 12:	Fitting of polynomial regression by orthogonal methods, multiple regression, and examination of regression equation.
Week 13:	Concept of Robust procedures, Robustness of sample mean, Sample standard deviation, Chi-square test and Student's t-test.
Week 14:	Sample size determination for testing and estimation procedures (complete and censored data) for normal, exponential, Weibull and gamma distributions.

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial	Practical/ Practice (30 Hours)
DSC 1c: Survey Sampling	**4**	**3**	**0**	**1**

Course Objectives:

1. The main objective of this course is to learn techniques in survey sampling with practical applications in daily life which would be beneficial for the students to their further research.
2. To provide tools and techniques for selecting a sample of elements from a target population keeping in mind the objectives to be fulfilled and nature of population.

Course Learning Outcomes:

1. Understand the distinctive features of sampling schemes and its related estimation problems 2.
2. 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.

3. Learn about the methods of post–stratification (stratified sampling) and controlled sampling and also double sampling procedure with unequal probability of selection.
4. Learn about the applications of sampling methods; systematic, stratified and cluster sampling.
5. Learn about the randomized response techniques.

Unit I: (10 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 (modelbased) approaches.

Unit II: (11 Hours)

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

Unit III: (12 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, Double (two-phase) sampling with special reference to the selection with unequal probabilities in at least one of the phases.

Unit IV: (12 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.

Suggested Readings:

1. Cochran, W.G. (2011). Sampling Techniques, 3rd Ed., Wiley Eastern John Wiley and Sons.
2. Murthy M.N. (1977). Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.

3. Singh, D. and Chaudhary, F. S. (2015). Theory and Analysis of Sample Survey Designs.
4. Mukhopadhyay, P. (2009). Theory and Methods of Survey Sampling, 2nd Edn., Prentice Hall of India, New Delhi.

Teaching Plan:

Week 1-2:	Basic ideas and distinctive features of sampling, Probability sampling designs, sampling schemes, inclusion probabilities and estimation.
Week 3:	Review of important results in simple and stratified random sampling.
Week 4-5:	Fixed (Design –based) and Superpopulation (modelbased) approaches.
Week 6-7:	Sampling with varying probabilities (unequal probability sampling) with or without replacement: pps, πps and non- πps sampling procedures and estimation based on them
Week 8:	Nonnegative variance estimation.
Week 9:	Two-way stratification, post-stratification, controlled sampling
Week 10:	Estimation based on auxiliary data (involving one or more auxiliary variables) under design-based and model-based approaches.
Week 11:	Double (two-phase) sampling with special reference to the selection with unequal probabilities in at least one of the phases.
Week 12:	Systematic sampling and its application to structured populations, Cluster sampling (with varying sizes of clusters).
Week 13:	Two-stage sampling (with varying sizes of first-stage units),
Week 14:	Randomized response techniques

List of Practicals:

1. To select SRS with and without replacement.
2. For SRSWOR and SRSWR, estimate mean, standard error, the sample size.
3. Ratio and Regression estimation: Calculate the population mean or total of the population. Calculate mean squares. Compare the efficiencies of ratio and regression estimators relative to SRS.
4. Cluster sampling: estimation of mean or total, variance of the estimate, estimate of intra-class correlation coefficient, efficiency as compared to SRS.

5. PPS (Probability Proportional to Size) and πps (Horvitz-Thompson framework)

Discipline -Specific Elective (DSE) Courses

Discipline -Specific Elective (DSE) Courses- 1a: Analysis

Course Title and Code	Credits	Credit Distribution of Course		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical
DSE 1a: Analysis	4	3	1	0

Course Objectives: The main objective of this course is to introduce students the knowledge of real field and complex field with their properties and relativity between complex plane and real line. These properties and relations provide 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:

1. Understand existence of integral and their evaluation.
2. Apply convergence theorems of sequence and series of real valued function and complex valued functions.
3. Understand change of multiple integral into line integral.
4. Learn how apply real and complex-analytic methods to problems in probability theory.
5. Understand complex region and relativity between complex plane and real line.
6. Analyze power series, Laurent series, and residue calculus.
7. Solve contour integrals.
8. 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.

Suggested Readings:

1. Brown, J. W. and Chirchill, R. V. (2009). Complex variables and Applications, McGraw Hill.
2. Bartle, R. G. (1976). Elements of Analysis, John Wiley & Sons.
3. Bak, J. and Newman, D. J. (1997). Complex Analysis, Springer.
4. Rudin, W. (1985). Principles of Mathematical Analysis, McGraw Hill.
5. Rose, K. A. (2004). Elementary Analysis: The Theory of Calculus, Springer (SIE).

Teaching Plan:

Week 1:	Functions of bounded variations. Total variation. Positive variation and negative variation. Expression of a function of bounded variation in terms of monotonically increasing functions.
Week 2-3:	Riemann integration. Inequalities of upper and lower sums. Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums. Riemann integrability of continuous functions. Monotonic functions and functions with finite number of discontinuities.
Week 4:	Intermediate value theorem for integrals. Fundamental theorem of Calculus. Riemann-Stieltjes integral. Evaluating Riemann-Stieltjes integral using definition and also, by reducing it to Riemann integral.

Week 5:	Multiple integrals and their evaluation by repeated integration. Change of variable in multiple integration. Differentiation under integral sign. Leibnitz rule. Dirichlet integral. Liouville's extension.
Week 6:	Pointwise and uniform convergence of sequence of functions. Cauchy's criteria and Weirstrass M-test. Continuity, differentiability and integrability of a limit function.
Week 7:	Uniform convergence of series of functions. Conditions for continuity, differentiability and integrability of the sum function. Maxima-minima of functions of several variables.
Week 8-9:	Properties of complex numbers. Region in the complex plane. Functions of complex variable. Limit, continuity and differentiability of functions of complex variable. Cauchy Riemann equations. Sufficient conditions for differentiability. Analytic functions and examples of analytic functions.
Week 10:	Contour integrals and its example. Upper bounds for moduli of contour integrals. M-L formula. Antiderivatives. Cauchy theorem. Cauchy-Goursat theorem and Cauchy integral formula.
Week 11:	Liouville's theorem and fundamental theorem of Algebra. Convergence of sequence and series. Absolute and uniform convergence of power series.
Week 12:	Taylor's series and Laurent's series and their examples. Uniqueness of series representation of power series.
Week 13:	Singular points. Classification of singularity. Residue at poles and its examples. Residue at infinity with examples.
Week 14:	Cauchy residue theorem. Evaluation of definite integrals and real integrals involving sine and cosines.

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

Course Title & Code	**Credits**	**Credit Distribution of the Course**		
		Lecture (45 Hours)	**Tutorial**	**Practical/ Practice (30 Hours)**

DSE 1b: Time Series Analysis	**4**	**3**	**0**	**1**

Course Objectives: The main objective is to teach the time series modelling and the concept of forecasting and future planning.

Course Learning Outcomes: After completing the paper, students will be able to apply:

1. Time series analysis concepts to practical data scenarios.
2. Techniques to identify and analyze trends and seasonality.
3. Various time series models, including MA, AR, ARMA, and ARIMA, for data modeling.
4. Time series models for effective forecasting.
5. Information criteria (AIC, BIC) to select the most suitable models.
6. Yule-Walker equations to analyze AR processes.
7. Methods to address nonstationarity in time series data.
8. 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 nonstationarity in time series, random walk model, Dickey-Fuller test for unit root. ARCH and GARCH Processes, order identification, estimation, diagnostic.

Suggested Readings:

1. Box, George E. P., Gwilym M. Jenkins, Gregory C. Reinsel, Greta M. Ljung . (2015) Time Series Analysis – Forecasting and Control, 5th Edition, Wiley.
2. Brockwell, P. J. and Davies, R. A. (2009) Introduction to Time Series and Forecasting (2nd Edition Indian Print). Springer.
3. Chatfield, C. (1975) The Analysis of Time series: Theory and Practice. Fifth Ed. Chapman and Hall.
4. Chatfield, C. (2003) Analysis of Time Series, An Introduction, 6th Edition, CRC Press.
5. Jonathan, D. C. and Kung, S.C. (2008). Series Analysis with application in R. Second Ed. Springer
6. Kendall, M. G. and Ord, J. K. Time Series (Third edition), Edward Arnold.
7. Montgomery, D. C. and Johnson, L. A. (1977). Forecasting and Time series Analysis, McGraw Hill.
8. Montgomery, D.C., Jennings, C. and Kulahci, M. (2016). Introduction to Time Series Analysis and Forecasting. Second Ed., Wiley.
9. Shumway, R.H. and Stoffer, D.S. (2017). Time Series Analysis and Its Applications: With R Examples. Fourth Edition. Springer.

Teaching Plan:

Week 1:	Time series as a stationary or nonstationary stochastic process, sample autocovariance function (acvf)
Week 2:	autocorrelation function (acf) at lag k, partial autocorrelation function (pacf)
Week 3:	correlogram, lag operators and linear filters, Ergodicity and Stationarity
Week 4:	Wald decomposition, Generic linear process and its acvf, acf
Week 5:	Autoregressive (AR) process, moving average (MA) process
Week 6:	acf and pacf for AR and MA processes,
Week 7:	Yule-Walker equations for AR processes.
Week 8:	Stationarity and invertibility conditions, ARIMA (p,d,q) model

Week 9:	Estimation of parameters for AR, MA, ARMA and ARIMA processes
Week 10:	Identification of processes with ACF PACF,
Week 11:	Model estimation techniques-AIC, AICC, BIC, etc.
Week 12:	Forms of nonstationarity in time series, random walk model
Week 13:	Dickey-Fuller test for unit root. ARCH and GARCH Processes
Week 14:	Order identification, estimation, diagnostic tests.

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.

Course Title & Code	**Credits**	**Discipline-Specific Elective (DSE) Course- 1c: Bio-Statistics**		
		Credit Distribution of the Course		
		Lecture (45 Hours)	**Tutorial**	**Practical/ Practice (30 Hours)**
DSE 1c: Bio-Statistics	**4**	**3**	**0**	**1**

Course Objectives: Biostatistics is one area of Applied Statistics that is concerned with the application of statistical methods to medical, biological, epidemiological and health related aspects of all forms of life.

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

1. Develop understanding of time-to-event data in Biomedical Sciences.
2. Summarizing clinical data using displays, parametric and non- parametric approaches.
3. Understanding concepts of conditional and inverse probabilities as applied to survival data.
4. Establishing meaningful relationships for causative and consequential health factors.
5. Understand survival patterns in presence and in absence of censoring.
6. Account for censored patterns and their implications.
7. Estimation of failure and hazard forms based on patient data records.
8. Formulate and interpret stochastic models for specific-disease data sets.
9. Comprehend basis and construction of clinical trials for different stages.
10. 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: (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.

Suggested Readings:

1. Biswas, S. (1995). Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Wiley Eastern Ltd.
2. Collett, D. (2003). Modelling Survival Data in Medical Research, Chapman & Hall/CRC.
3. Cox, D.R. and Oakes, D. (1984). Analysis of Survival Data, Chapman and Hall.
4. Dabholkar A.R. (1999) Elements of Bio Metrical Genetics. Concept Publishing Co. , New Delhi.
5. Elandt Johnson R.C. (1971). Probability Models and Statistical Methods in Genetics, John Wiley & Sons.
6. Ewens, W. J. (1979). Mathematics of Population Genetics, Springer Verlag.
7. Ewens, W. J. and Grant, G.R. (2001). Statistical methods in Bio informatics: An Introduction, Springer.
8. Friedman, L.M., Furburg, C. and DeMets, D.L. (1998). Fundamentals of Clinical Trials, Springer Verlag.
9. Gross, A. J. And Clark V.A. (1975). Survival Distribution; Reliability Applications in Biomedical Sciences, John Wiley & Sons.
10. Indrayan, A. (2008). Medical Biostatistics, 2^{nd} ed., Chapman & Hall/CRC.
11. Lee, Elisa, T. (1992). Statistical Methods for Survival Data Analysis, John Wiley & Sons.
12. Li, C.C. (1976). First Course of Population Genetics, Boxwood Press.
13. Liu Xian. (2012) Survival Analysis: Model and Applications. Wiley.
14. Miller, R.G. (1981). Survival Analysis, John Wiley & Sons.
15. Robert F. Woolson (1987). Statistical Methods for the analysis of biomedical data, John Wiley & Sons.
16. Tattar P.N and Vaman H.J. (2023) Survival Analysis. CRC Press.

Teaching Plan:

Week 1:	Analysis of Medical, Epidemiologic and Clinical Data: Studying association between a disease and a characteristic: (a) Types of studies in Epidemiology and Clinical Research
Week 2:	Prospective study (ii) Retrospective study (iii) Cross-sectional data, (b) Dichotomous Response and Dichotomous Risk Factor: 2x2 Tables
Week 3:	Expressing relationship between a risk factor and a disease (d) Inference for relative risk and odds ratio for 2x2 table
Week 4:	Sensitivity, specificity and predictivities. Clinical Trials: Its Planning and its Four Phases.
Week 5:	Special Survival Features: Censoring and its types. Study time and Patient time.
Week 6:	Survival Analysis: Survival Distributions and their Properties *viz.* Exponential, Weibull, Gamma, Rayleigh and Lognormal.
Week 7:	Estimation of Survivor and Hazard Functions: Life Table, Kaplan-Meier and Nelson-Aalen Estimates.
Week 8:	Estimation of Mean survival time and variance for Type I and Type II Censored data with examples.
Week 9:	Cox-Proportional Hazards Model: Its Linear Component, Fitting, Hypothesis Tests. Estimating Hazard and Survivor Function.
Week 10:	Kaplan Meier Estimate, Hazard and Cumulative Incidence Functions, Modelling.
Week 11:	Cause Specific Hazard and Incidence, Model Checking. Sample Size Requirements for a Survival Study.
Week 12:	Multiple Factor Hypothesis for Process of Heredity. Medelian Population: Gene Frequency and Genotype Frequency.
Week 13:	Hardy Weinberg Law: Multiple Alleles, Two or More Pairs of Genes, Linkage of Genes, Sex Linked Genes.
Week 14:	Influence of Gene Frequencies on Population Mean. Breeding Value of Genotypes. Dominance Deviation.

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) Courses-
1d: Official And National Development Statistics

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical/ Practice
DSE 1d: Official and National Development Statistics	4	3	1	0

Course Objectives: This course will provide the important information on Indian Official Statistical System.

Course Learning Outcomes:

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

1. Learn about the role and function of National and State Statistical Organizations.
2. Knowing important sectors of Indian official statistics system (National and State) with their important regular publications.
3. Understanding important data collection mechanism in different sectors.
4. Finding important reasons for non-response while collecting Official Statistics.
5. Learning concepts of National Accounts with the release.
6. Finding statistics related to industries, foreign trade, balance of payment, cost of living,

inflation, educational and other social statistics.

7. 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.

Suggested Readings:

1. Saluja, M.R. (2017). Measuring India. The Nation's Statistics System, OUP Catalogue, Oxford University Press.
2. Directorate General of Commercial Intelligence and Statistics (DGCIS). Monthly Statistics of the Foreign Trade of India. Calcutta: DGCIS.
3. Panse, V.G. (1954): Estimation of Crop Yields. Food and Agricultural Organization.
4. UNESCO. Principles and recommendations for population and housing censuses. Revision 3. New York: United Nations.

5. Ministry of Statistics and Programme Implementation (MoSPI). Statistical System in India. Government of India.
6. Reserve Bank of India. Handbook of Statistics on the Indian Economy. Mumbai: Reserve Bank of India
7. Ministry of Agriculture and Farmer's Welfare, Government of India. Pocket Book of Agricultural Statistics.

Forest Survey of India (2023). India State of Forest Report. Dehradun: Forest Survey of India

Teaching Plan:

Week 1-2:	An overview of National and International statistical systems. National Statistical Organization: Vision and Mission, Central Statistical Office (CSO), National Sample Survey Office (NSSO).
Week 3:	Roles and responsibilities of CSO and NSSO; Important publications. State Indian statistical organizations
Week 4:	Important role, function and activities of Indian State statistical organizations. Organization of large scale sample surveys.
Week 5:	National Statistical Commission: Need, constitution, its role, functions, etc.
Week 6:	Legal acts/ provisions/ support for Official Statistics.
Week 7:	Data collection & compilation mechanism, processing, analysis and dissemination systems, agencies involved,
Week 8:	Population growth in developed and developing countries, evaluation and performance of family welfare programmes.
Week 9:	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.
Week 10:	Important surveys & censuses, indicators, agencies, and usages, etc.
Week 11:	National Accounts: Definition, basic concepts, issues, the strategy, collection of data and release.
Week 12:	System of collection of agricultural and forestry statistics, crop forecasting and estimation, productivity, fragmentation of holdings, support prices.

Week 13:	Statistics related to industries, foreign trade, balance of payment, cost of living, inflation, educational and other social statistics.
Week 14:	Socio-Economic indicators, Gender Awareness/Statistics.

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial	Practical/ Practice (30 Hours)
GE 1b: Statistical Computing Using R	**4**	**3**	**0**	**1**

Course Objectives: The main objectives of this course are:

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

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

1. Carry out data analysis using R software.
2. Effectively visualize and summarize the data.
3. 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.

Suggested Readings:

1. Crawley, M.J. (2013). The R Book, 2nd ed., John Wiley.
2. Davies, T. M. (2016). The Book of R: A First Course in Programming and Statistics, No Starch Press, San Francisco.
3. Field, A., Miles, J. and Field, Z. (2012). Discovering Statistics using R, Sage, Los Angels.
4. Kabacoff, R.I. (2015). R in Action: Data Analysis and Graphics in R, 2nd ed., Manning

Publications.

Teaching Plan:

Week 1-2:	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.
Week 3-4:	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.
Week 5-6:	Basic statistics: Descriptive statistics, frequency and contingency tables, outlier detection, testing of normality, basics of statistical inference in order to understand hypothesis testing, computing p-value and confidence intervals.
Week 7-8:	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.
Week 9-10:	Correlation: Correlations between quantitative variables and their associated significance tests. Regression Analysis: Fitting simple and multiple regression models, 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.
Week 11:	ANOVA: Fitting and interpreting ANOVA type models, evaluating model assumptions, basic experimental designs: CRD, RBD, LSD and factorial experimental designs.

Week 12-14:	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: For missing and incomplete data problems.

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 Courses

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture	Tutorial	Practical/ Practice (60 Hours)
SB 1a: Data Analysis Using Excel	2	0	0	2

Course Objectives

This course is designed to provide students with a solid understanding of fundamental statistical concepts and practical experience in using Microsoft Excel for data analysis. By the end of the course, students will 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:

1. Grasp fundamental statistical concepts and their real-world applications.
2. Conduct both descriptive and inferential statistical analyses using Excel functions and tools.
3. 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.

Suggested readings:

1. Kanji, G. K. (2006). 100 Statistical Tests. SAGE Publications, London.
2. Montgomery, D. C. (2013). Design and Analysis of Experiments. John Wiley & Sons, New York.
3. Panneerselvam, R. (2024). Business Statistics Using Excel: A Complete Course in Data Analytics. Routledge, New York.
4. Rajagopalan, V. (2006). Selected Statistical Tests. New Age International Publishers, New Delhi.
5. Schmuller, J. (2009). Statistical Analysis with Excel for Dummies. Wiley, Indiana.
6. Searle, S. R., & Khuri, A. I. (2017). Matrix Algebra Useful for Statistics. John Wiley & Sons, New York.

SEMESTER II

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical/ Practice
DSC 2a: Statistical Inference	4	3	1	0

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:

1. Apply various estimation and hypothesis testing procedures to deal with real life problems.
2. Demonstrate a comprehensive understanding of Fisher Information, Lower bounds to variance of estimators, MVUE.
3. 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.

Suggested Readings:

1. Bartoszynski, R. and Bugaj, M.N. (2007). Probability and Statistical Inference, John Wiley & Sons.
2. Ferguson, T.S. (1967). Mathematical Statistics, Academic Press.
3. Kale, B.K. (1999). A First Course on Parametric Inference, Narosa Publishing House.
4. Lehmann, E.L. (1986). Theory of Point Estimation, John Wiley & Sons.
5. Lehmann, E.L. (1986). Testing Statistical Hypotheses, John Wiley & Sons.
6. Rohatgi, V.K. and Saleh, A.K. Md. E. (2005). An Introduction to Probability and Statistics, 2nd Edn., John Wiley & Sons.
7. Rao, C.R. (1973). Linear Statistical Inference and Its Applications, Wiley Eastern Ltd., New Delhi.
8. Zacks, S. (1971). Theory of Statistical Inference, John Wiley & Sons.

Teaching Plan:

Week 1-2:	Minimal sufficiency and ancillarity.
Week 3:	Exponential families and Pitman families.
Week 4:	Invariance property of Sufficiency under one-one transformations of sample and parameter spaces.
Week 5:	Fisher Information for one and several parameters models.
Week 6:	Lower bounds to variance of estimators for one and several parameters models, necessary and sufficient conditions for MVUE.
Week 7:	Neyman-Pearson fundamental lemma and its applications.
Week 8:	UMP tests for simple null hypothesis against one-sided alternatives and for one-sided null against one-sided alternatives in one parameter exponential family.
Week 9:	Extension of these results to Pitman family when only upper or lower end depends on the parameters and to distributions with MLR property.
Week 10:	Non-existence of UMP tests for simple null against two-sided alternatives in one parameter exponential family.
Week 11:	Families of distributions with monotone likelihood ratio and UMP tests.
Week 12:	Interval estimation, confidence level, construction of shortest expected length confidence interval.

Week 13:	Uniformly most accurate one-sided confidence Interval.
Week 14:	Its relation to UMP tests for one-sided null against one-sided alternative hypotheses.

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial	Practical/Practice (30 Hours)
DSC 2b: Design of Experiments	**4**	**3**	**0**	**1**

Course Objectives: This course provides the students the 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:

1. 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.
2. Design and analyse incomplete block designs, understand the concepts of orthogonality, connectedness and balance.
3. 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.
4. Identify the effects of different factors and their interactions and analyse factorial experiments.
5. Construct complete and partially confounded factorial designs and perform their analysis.

6. Apply Split-plot designs and their analysis in practical situations.
7. 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.

Suggested Readings:

1. Chakrabarti, M.C. (1962). Mathematics of Design and Analysis of Experiments, Asia Publishing House, Bombay.
2. Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments, Wiley Eastern Limited.
3. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. First Indian Reprint 2006.
4. Dey, A. (1986). Theory of Block Designs, John Wiley & Sons.
5. Hinkelmann, K. and Kempthorne, O. (2005). Design and Analysis of Experiments, Vol.

2: Advanced Experimental Design, John Wiley & Sons.
6. John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan Co., New York.
7. Kshirsagar, A.M. (1983). A Course in Linear Models, Marcel Dekker, Inc., N.Y.
8. Montgomery, D. C. (2005). Design and Analysis of Experiments, 6th ed., John Wiley & Sons.
9. Raghavarao, D. (1970). Construction and Combinatorial Problems in Design of Experiments, John Wiley & Sons.
10. Raghavarao, D. and Padgett, L. V. (2005). Block Designs: Analysis, Combinatorics, and Applications, World Scientific.

Teaching Plan:

Week 1:	Review of linear estimation and basic designs, elimination of heterogeneity in two directions.
Week 2:	ANOVA, Fixed effect models (2-way classification with equal, unequal and proportional number of observations per cell).
Week 3:	ANOVA, Random and Mixed effect models (2-way classification with m (>1) observations per cell).
Week 4-5:	Incomplete Block Designs. Concepts of Connectedness, Orthogonality and Balancedness.
Week 6-7:	Intrablock analysis of Generic Incomplete Block design. B.I.B designs with and without recovery of inter block information.
Week 8:	Finite fields.
Week 9:	Finite Geometries- Projective geometry and Euclidean geometry.
Week 10:	Construction of complete set of mutually orthogonal Latin squares. Construction of B.I.B.D. using finite Abelian groups and MOLS.
Week 11:	Construction of B.I.B.D using finite geometry and method of differences.
Week 12-13:	Symmetrical factorial experiments (s^m, where s is a prime or a prime power), Confounding in s^m factorial experiments through Pencils.
Week 14:	S^{k-p} fractional factorial where s is a prime or a prime power. Split-plot experiments.

List of Practicals:

1. ANOVA for two –way classification:
   i. Fixed effect model: equal, unequal and proportional number of observations.
   ii. Random effect model with 'm' observations per cell.
   iii. Mixed effect model with 'm' observations per cell.
2. IBD:
   i. Intrablock analysis
   ii. Inter block analysis
3. Complete s^m symmetrical factorial designs with s=3.
4. Completely confounded s^m symmetrical factorial designs with s=3, m=2.
5. Partially confounded s^m symmetrical factorial designs with s=3, m=2.
6. sk-p fractional factorial designs with s=3, k(≤4).
7. Split-plot designs.

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical/ Practice
DSC 2b: Stochastic Processes	4	3	1	0

Course objectives: The main objective of this course is 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:

1. Use notions of long-time behaviour including transience, recurrence, and equilibrium in applied situations such as branching processes and random walk.

2. Construct transition matrices for Markov dependent behaviour and summarize process information
3. Use selected statistical distributions for modeling various phenomena.
4. 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.

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, 3rd Edn., John Wiley & Sons.
3. Karlin, S. and Taylor, H.M. (1975). A first course in Stochastic Processes, Second ed. Academic Press
4. Medhi, J. (1994). Stochastic Processes, Seconded Wiley Eastern Ltd.
5. Prabhu, N.U. (2007). Stochastic Processes: Basic Theory and its Applications, World Scientific
6. Ross, S. M. (1996). Stochastic Processes, John Wiley and Sons, Inc
7. Taylor, H.M. and Karlin, S. (1998). An Introduction to Stochastic Modelling, 3rd ed., Academic Press.

Teaching Plan:

Week 1:	Review of basic Probability Concepts. Introduction to Stochastic Processes. Deterministic and Stochastic Exponential Growth Models. Stationary and Evolutionary Processes.
Week 2:	Poisson Processes: Poisson Distribution and Poisson Process. Arrival, Interarrival and Conditional Arrival Distributions. Nonhomogeneous Processes.
Week 3:	Poisson Processes: Law of Rare Events and Poisson Process. Poisson Point Process.
Week 4:	Distributions associated with Poisson Process. Compound Poisson Processes.
Week 5:	Markov Chains: Transition Probability Matrices, Chapman- Kolmogorov equations, Some Examples and Classification of States
Week 6:	Markov Chains: Regular Chains and Stationary Distributions, Periodicity
Week 7:	Markov Chains: Limit theorems, Fundamental Matrix, Some Applications
Week 8:	Patterns for recurrent events: One-dimensional, two-dimensional and three-dimensional random walks.
Week 9:	Brownian Motion: Limit of Random Walk, Its Defining Characteristics and Peculiarities.
Week 10:	Brownian Motion: Its Variations: Standard Brownian Motion, Brownian Bridge, Brownian Motion Reflected at Origin, Geometric Brownian Motion, Brownian Motion with Drift.
Week 11:	Brownian Motion: Reflection Principle. Some Applications.
Week 12:	Renewal Processes: Preliminaries, Elementary Renewal Theorem, Delayed Renewal Processes.

Week 13:	Renewal Processes: Limit Theorems. Martingales: Definitions and some examples.
Week 14:	Stopping Times, Martingale Stopping Theorem, Wald Equation.

Discipline-Specific Elective (DSE) Courses

Discipline-Specific Elective (DSE) Courses - 2a: Linear Algebra

Course Title & Code	**Credits**	**Credit Distribution of the Course**		
		Lecture (45 Hours)	**Tutorial (15 Hours)**	**Practical/ Practice**
DSE 2a: Linear Algebra	**4**	**3**	**1**	**0**

Course Objectives: The main objective of this paper is to allow students to manipulate and understand multidimensional space.

Course Learning Outcomes: After completing this course students will

1. Demonstrate a deep understanding of vector spaces, subspaces, linear independence, basis, and dimension.
2. Analyze and interpret linear transformations, matrix representations, and change of basis, including orthogonality and inner product spaces.
3. Apply orthogonality and the Gram-Schmidt process in practical problems.
4. Compute eigenvalues, eigenvectors, and perform spectral and decomposition.
5. 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.

Suggested Readings:

1. Biswas, S. (1997). A Text Book of Matrix Algebra, 2nd ed., New Age International Publishers.
2. Golub, G.H. and Van Loan, C.F. (1989). Matrix Computations, 2nd ed., John Hopkins University Press, Baltimore-London.
3. Hadley, G. (2002). Linear Algebra. Narosa Publishing House (Reprint).
4. Rao, C.R. (1973). Linear Statistical Inferences and its Applications, 2nd ed., John Wiley & Sons.
5. Robinson, D.J.S. (1991). A Course in Linear Algebra with Applications, World Scientific, Singapore.
6. Searle, S.R. (1982). Matrix Algebra useful for Statistics, John Wiley & Sons.
7. Strang, G. (1980). Linear Algebra and its Application, 2nd ed., Academic Press, London New York.

Teaching Plan:

Week 1:	Concept of groups and fields with examples, Vector spaces and Subspaces with examples, Direct sum of subspaces.
Week 2:	Algebra of subspaces viz. sum, intersection, union etc, Linear combinations, Spanning sets, Linear spans
Week 3:	Linear dependence and independence in vector spaces, Row and Column space of a matrix, Basis and Dimensions.
Week 4:	Linear Transformations, Kernel and Image of a linear transformation, Rank and Nullity.
Week 5:	Matrix representation of a linear operator, Change of Basis, Similarity.
Week 6:	Inner product spaces with examples, Cauchy-Schwarz inequality with applications.
Week 7:	Orthogonality, Orthonormal sets and Bases, Gram Schmidt Orthogonalization Process.
Week 8:	Eigenvalues and eigenvectors.
Week 9:	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.
Week 10:	Algebraic and geometric multiplicity of characteristic roots, Diagonalization of matrices, Factorization of a matrix, Eigenvalues and eigenvectors for solution of Differential equations
Week 11-12:	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.
Week 13-14:	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.

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture (45 Hours)	Tutorial	Practical/ Practice (30 Hours)
DSE 2b: Non-Parametric Inference	4	3	0	1

Course Objectives:

This course will provide 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:

1. Solve hypothesis testing problems where the conditions for the traditional parametric inferential tools to be applied are not fulfilled.
2. 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, Asymptotic distribution of U-statistics, Confidence interval for population quantile and scale parameter, 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)

Nonparametric density estimation, nonparametric regression estimation. 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, 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. Concept of power and robustness, elements of bootstrapping.

Suggested Readings:

1. David, H.A. and Nagaraja, H. N. (2003). Order Statistics, Third Edition, John Wiley & Sons.
2. Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, 3rd ed., Marcel Dekker.
3. Hettmansperger, T.P. (1984). Statistical inference Based on Ranks, John Wiley & Sons.
4. Randles, R.H. and Wolfe, D.A. (1979). Introduction to the Theory of Nonparametric Statistics, John Wiley & Sons.
5. Rohatgi, V.K. and Saleh, A.K. Md. E. (2005). An Introduction to Probability and Statistics, 2^{nd} ed., John Wiley & Sons.

Teaching Plan:

Week 1:	Review of order statistics, Distribution-free statistics over a class, Counting statistics, ranking statistics, Statistics utilizing counting and ranking.
Week 2:	Asymptotic distribution of U-statistics, Confidence interval for population quantile and scale parameter.
Week 3:	Point estimation. Estimators associated with distribution free test statistics.
Week 4:	Exact small-sample and asymptotic properties of the Hodges-Lehmann location estimators.
Week 5:	Nonparametric density estimation, Nonparametric regression estimation. Tests based on length of the longest run, runs up and down.
Week 6:	Kolmogorov-Smirnov two sample statistic. Rank order statistics: Correlation between ranks and variate values.

Week 7:	One sample, paired sample and two sample problems, distribution properties of linear rank statistics.
Week 8:	Tests for equality of k independent samples: Kruskal-Wallis one way ANOVA test.
Week 9:	Measures of Association for bivariate samples: Kendall's Tau coefficient.
Week 10:	Spearman's coefficient of Rank correlation, relations between R and T; E (R), τ and ρ.
Week 11:	Measures of association in multiple classifications: Friedman's two-way ANOVA by ranks in a k x n table.
Week 12-13:	Coefficient of Concordance of k sets of rankings of n objects, Coefficient of Concordance of k sets of incomplete rankings.
Week 14:	Concept of power and robustness, elements of bootstrapping.

List of Practicals:

1. Point estimation. Estimators associated with distribution free test statistics.
2. Kolmogorov-Smirnov 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**		
		Lecture (45 Hours)	**Tutorial**	**Practical/ Practice (30 Hours)**
DSE 2c: Statistical Quality Control	**4**	**3**	**0**	**1**

Course Objectives: The main purpose of this paper is 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:

1. Describe the DMAIC process (define, measure, analyze, improve, and control).
2. Demonstrate to use the methods of statistical process control and to determine when an out-of-control situation has occurred.
3. Design and use Cumulative sum chart, tabular Cumulative sum chart and V-mask schemes for detecting small shifts of the mean from goal conditions.
4. Choose an appropriate sampling inspection technique.
5. Gain the ability to understand the concept of errors in making inference
6. Understand the concept of OC and ARL of control chart.
7. 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.

Suggested Readings:

1. Biswas, S. (1996). Statistics of Quality Control, Sampling Inspection and Reliability, New Age International Publishers.
2. Duncan A.J. (1974). Quality Control and Industrial Statistics, IV Edision, Taraporewala and Sons.
3. Ott, E. R. (1977). Process Quality Control (McGraw Hill) Montgomery, D. C. (2005).
4. Introduction to Statistical Quality Control, 5th ed., John Wiley & Sons.
5. Wetherill, G. B. (1977). Sampling Inspection and Quality Control, Halsted Press.
6. Wetherill, G.B. Brown, D.W. (1991). Statistical Process Control Theory and Practice, Chapman & Hall.

Teaching Plan:

Week 1:	Basic concepts of process monitoring and process control, Generic theory and review of attributes
Week 2:	Review of variable control charts, errors in making inferences from control charts, OC and ARL of control charts.
Week 3:	Moving average and exponentially weighted moving average control chart (EWMA)
Week 4:	cumulative sum control chart (CUSUM) using V-mask and decision intervals
Week 5:	Economic design of $\overline{X}$ Chart.
Week 6:	Methods and philosophy of statistical process control
Week 7:	Process and measurement system capability analysis: process capability ratios
Week 8:	process capability analysis using a control chart
Week 9:	Gauge and measurement system capability studies

Week 10:	Review of sampling inspection techniques, single sampling plans
Week 11:	Double sampling plans, multiple sampling plans
Week 12:	Sequential sampling plans and their properties
Week 13:	Dodge's continuous sampling inspection plans for inspection by variables for one-sided specifications
Week 14:	Dodge's continuous sampling inspection plans for inspection by variables for two-sided specifications.

List of Practicals: Students will be required to do practical based on topics listed below

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		
		Lecture (45 Hours)	Tutorial (15 Hours)	Practical/ Practice
DSE 2d: Reliability Theory	4	3	1	0

Course Objectives:

1. Introduces fundamental reliability concepts, including reliability, availability, and maintainability, and explores their interrelationships.
2. Define reliability and explain its significance in engineering and systems.
3. Learn key reliability measures such as failure rate, mean time to failure (MTTF), and mean time between failures (MTBF).

4. Understand redundancy techniques and their applications in improving system reliability.
5. Understand new better than used (NBU), decreasing mean residual life (DMRL), and new better than used in expectation (NBUE) properties.

Course Learning Outcomes:

1. To analyze the system reliability, including coherent systems and their reliability estimation.
2. Investigate reliability in systems with imperfect switches and priority redundant systems.
3. Explain the loss of memory property of the exponential distribution and its significance in failure modeling.
4. 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.

Suggested Readings:

1. Bain, L.J. and Engelhardt, M. (1991). Statistical Analysis of Reliability and Life- Testing Models, Marcel Dekker Inc., U.S.A.
2. Martz, H.F. and Wailer, R.A. (1982). Bayesian Reliability Analysis, John Wiley and Sons, Inc., New York.
3. Sinha, S.K. (1986). Reliability and Life-Testing, Wiley Eastern Ltd., New Delhi.

Teaching Plan:

Week 1-2:	Reliability concepts & measures, components and systems, coherent system, reliability of the coherent system.
Week 3:	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.
Week 4:	System components and configurations: Series, Parallel, Series-Parallel, Parallel-Series, and K-out of –N- system.
Week 5:	Series- strength reliability and its estimation. Redundancy: Types of Redundancies, Repairable system
Week 6:	Maintenance Policies, System with imperfect switch, Priority Redundant system.
Week 7:	Model Plotting techniques: Reliability function with Markov model
Week 8:	Two unit cold standby & parallel unit system with constant failure rate, Arbitrary Repair rates.
Week 9:	Regenerative point Techniques. Stress strength reliability and its estimation. IFR, IFRA, NBU, DMRL and NBUE and their duals
Week 10:	Loss of memory property of the exponential distribution.
Week 11:	Practical on Measuring failure rates of electrical/hypothetical components using historical data.
Week 12:	Practical on Estimating Mean Time to Failure (MTTF) and Mean Time between Failures (MTBF).

Week 13:	Practical on Evaluating series, parallel, and mixed configurations using reliability block diagrams.
Week 14:	Practical on Evaluating cost-benefit analysis of preventive vs corrective maintenance strategies.

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

Course Title and Code	Credits	Credit Distribution of Course		
		Lecture (30 Hours)	Tutorial	Practical (60 Hours)
DSE 2e: Computational Techniques	**4**	**2**	**0**	**2**

Course Objectives: The main objective of this course is to allow the students 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:

1. Simulate statistical models.
2. Understand linear models and distinguish between fixed, random and mixed effects models.
3. Learn and apply regression technique in their area of study.
4. 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.

Suggested Readings:

1. Agresti, A. (2015). Foundations of Linear and Generic ized Linear Models, John Wiley, New Jersey.
2. Chatterjee, S. and Hadi, A.S. (2012). Regression Analysis by Example, 5th ed., John Wiley, New Jersey.
3. Cryer, J.D. and Chan, K. (2008). Time Series Analysis: With Applications in R, Springer, New York.
4. Fox, J. and Weisberg, S. (2011). An R Companion to Applied Regression, 2nd ed., Sage.
5. Kroese, D.P. and Chan, J.C.C. (2014). Statistical Modeling and Computation, Springer.
6. Montgomery, D.C. (2001). Designs and Analysis of Experiments, John Wiley & Sons, New York.
7. Montgomery, D.C., Jennings, C.L. and Kulahci, M. (2008). Introduction to Time Series Analysis and Forecasting, John Wiley, New Jersey.
8. Ross, S.M. (2006). Simulation, 4th ed., American Press, USA.
9. Voss, J. (2014). An Introduction to Statistical Computing, John Wiley.
10. Weisberg, S. (2014). Applied Linear Regression, 4th ed., John Wiley,

Teaching Plan:

Week 1:	Probability Distributions: Bernoulli, Binomial, Poisson, Multinomial, Uniform, Exponential, Gamma, Beta, Normal, Chi Square, t and F distribution.
Week 2-3:	Simulation: Random number generation, simulating statistical models, Monte Carlo Methods.
Week 4-5:	Linear Models: Fixed, random and mixed effects models, ANOVA: one was and two way, ANOCOVA.
Week 6-7:	Regression Models: Simple and Multiple Linear Regression, Forward, Backward and stepwise regression, Residual analysis. Diagnostics and tests for violations of model assumptions: Multi-co-linearity, Autocorrelation and Homoscedasticity.
Week 8-10:	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.
Week 11:	Time Series: Stationary and nonstationary time series, Autocorrelation and Auto-covariance functions and their properties, Tests for trend and seasonality.
Week 12-14:	Stationary processes: Moving average (MA) process, Auto-regressive (AR) process, ARMA, ARIMA and SARIMA models. Box-Jenkins model, Estimation of mean, auto-covariance and auto-correlation function under large sample theory, forecasting.

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		
		Lecture (30 Hours)	Tutorial	Practical/ Practice (60 Hours)
GE 2b: Statistics for Research and Management Studies	4	2	0	2

Course Objectives: The main objectives of this course are:

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

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

1. Know different types of data produced in their area of study.
2. Create, manage, visualize, and summarize datasets.
3. Use and understand the inferential procedures.
4. Apply suitable sampling design.
5. Understand and apply basic designs.
6. Apply regression techniques.
7. 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. ANOCOVA, 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.

Suggested Readings:

1. Agresti, A. (2015). Foundations of Linear and Generic ized Linear Models, John Wiley, New Jersey.
2. Cochran, W.G. (2011). Sampling Techniques, 3rd ed., Wiley Eastern John Wiley & Sons.
3. Cochran, W.G. (2011): Sampling Techniques (3rd Ed.), Wiley Eastern John Wiley and Sons.
4. DeGroot, M.H. and Schervish, M.J. (2012). Probability and Statistics, 4th ed., Pearson Education.
5. Field, A., Miles, J. and Field, Z. (2012). Discovering Statistics using R, Sage, Los Angels.
6. Judd, C. M., McClelland, G. H. and Ryan, C.S. (2009). Data Analysis: A Model Comparison Approach, 2nd ed., Routledge, New York.
7. Montgomery, D.C. (2001). Design and Analysis of Experiments, 5th ed., John Wiley, New
8. Raghava Rao, D. (1988). Exploring Statistics, Markel Dekker, New York.
9. Rice, J.A. (1995). Mathematical Statistics and Data Analysis, 2nd ed., Duxbury Press.

10. Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S., Asok, C. (1984). Sampling Theories of Survey with Application, IOWA State University Press and Indian Society of Agricultural Statistics.
11. Taylor, J.K. and Cihon, C. (2004). Statistical Techniques for Data Analysis, 2nd ed., Chapman & Hall.

Teaching Plan:

Week 1-3:	Data types, scale of measurement, creating and managing dataset, 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.
Week 4-6:	Inference: Population and sample, parameter and statistic, estimates and estimators, estimation of parameters, type I and type II errors, p-value, statistical hypotheses, testing of hypothesis, inferences based on sample. Tests based on sampling distributions: Z, t, χ^2 and F.
Week 7-10:	Sampling Techniques: Simple random sampling, stratified random sampling, Cluster Sampling, Systematic sampling.
Week 11-14:	ANOVA for one way and two-way classification. ANOCOVA, analysis of basic designs, analysis of 2 level factorial experiments. Simple and multiple regression, logistic regression.

List of Practicals:

Students will be required to do practical based on topics listed below:

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 Courses

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

Course Title & Code	Credits	Credit Distribution of the Course		
		Lecture	Tutorial	Practical/ Practice (60 Hours)
SB 2a: Data Analysis Using Python	**2**	**0**	**0**	**2**

Course Objective:

This course introduces Python as a tool for statistical analysis, covering data visualization, probability, statistical inference, regression, sampling, and matrix algebra. Students will learn to fit probability distributions, conduct hypothesis testing, and apply statistical models to real-world data using key Python libraries

Course Learning Outcomes:

1. Understand Python programming for statistical analysis
2. Develop computational skills for probability, inference, regression, and matrix algebra
3. Perform hypothesis testing, distribution fitting and ANOVA
4. 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.

Suggested Readings:

1. Balagurusamy, E. (2016). Introduction to computing and problem solving using python. McGraw Hill Education, First Edition.
2. Halswanter, T. (2016). An Introduction to Statistics with Python: With Applications in the Life Sciences. Springer.
3. McKinney, W. (2012). Python for data analysis: Data wrangling with Pandas, NumPy, and IPython. " O'Reilly Media, Inc.".
4. Perkovic, L. (2015). Introduction to computing using python: An application development focus. John Wiley & Sons.
5. Vander Plas, J. (2016). Python data science handbook: Essential tools for working with data. " O'Reilly Media, Inc.

Teaching Plans:

Week 1:	Introduction to Python, Jupyter/Colab, NumPy basics.
Week 2:	Pandas for data handling, filtering, grouping, and EDA.
Week 3:	Data visualization with Matplotlib & Seaborn, customizing plots.
Week 4:	Probability distributions, Monte Carlo simulations, LLN & CLT.

Week 5:	Estimation (MLE, confidence intervals), hypothesis testing (Z-test, t-test).
Week 6:	Advanced tests (F-test, ANOVA, Wilcoxon, Kruskal-Wallis), post-hoc analysis.
Week 7-8:	Regression analysis, model assumptions, selection (AIC, BIC, Adjusted R^2), diagnostic plots.
Week 9:	Sampling techniques, population estimation, handling missing data.
Week 10:	Markov Chains, transition probabilities, steady-state, simulation.
Week 11-12:	Matrix algebra: operations, inverse and g-inverses, eigenvalues, solving linear systems.
Week 13–14:	Probability distribution fitting, Goodness-of-Fit tests, visualization.

DEPARTMENT OF STATISTICS
FACULTY OF MATHEMATICAL SCIENCES
UNIVERSITY OF DELHI, DELHI - 110007

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

First Year of Two Year PG Programme - Level 6

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

Second Year of Two Year PG Programme - Level 6.5

Semester	Discipline-Specific Core (DSC) Courses	Discipline-Specific Elective (DSE) Courses	Genric Elective	Skill Based/ Specialized Laboratory
III	3a Advanced Statistical Inference 3b Multivariate Analysis	3a Statistics in Finance 3b Statistical Quality Management 3c Advanced Survey Sampling 3d Advanced Theory of Experimental Designs 3e Operational Research 3f Acturial Statistics 3g Stochastic Models	3a Actuarial Statistics 3b Essentials of Survey Sampling and Experimental Design* 3c Applied Multivariate Statistics	3a Data Analysis Using R
IV	4a Generalized Linear Models 4b Econometrics	4a Bayesian Inference 4b Order Statistics 4c Applied Stochastic Processes 4d Advanced Statistical Computing and Data Mining 4e Statistical Decision Theory 4f Forestry and Environmental Statistics	4a Forestry and Environmental Statistics 4b Inferential Techniques	4a Data Analysis Using SPSS