Punyashlok Ahilyadevi Holkar Solapur University, Solapur

NAACAccredited-2022
'B^{++}'Grade (CGPA2.96)

Name of the Faculty: Science & Technology

CHOICE BASED CREDIT SYSTEM

(According to NEP 2020)

Syllabus: Statistics
Name of the Course: B.Sc. III (Sem. V & VI)

(Syllabus to be implemented from June 2026)

Punyashlok Ahilyadevi Holkar Solapur University, Solapur

Faculty of Science & Technology

Syllabus of B.Sc. Part-III- Statistics

Preamble:

The B.Sc. III Statistics program is designed to provide students with a comprehensive understanding of statistical concepts, methods and applications that are essential in modern scientific research, industry and decision-making processes. Statistics, as a discipline, plays a crucial role in collecting, analyzing, interpreting and presenting data in meaningful ways. The program aims to develop analytical thinking, quantitative reasoning and problem-solving abilities among students through theoretical knowledge and practical applications. It also emphasizes the use of statistical software and modern computational tools for data analysis, enabling students to address real-world problems effectively. The curriculum is structured to prepare students for higher education, research and diverse career opportunities in data science, healthcare, finance, industry, government and academia.

Aims: The aim of the course is to generate intelligent, skilled and competent graduates with adequate theoretical and practical knowledge in Statistics. The program seeks to develop conceptual understanding of statistical principles, methods and models along with appropriate analytical and computational skills for solving practical problems. The course also aims to inculcate logical reasoning, data interpretation abilities, research aptitude and ethical awareness in the application of statistical techniques across various disciplines.

Program Outcomes:

1. Enabling students to develop a positive attitude towards Statistics as an interesting, valuable and applicable subject of study.
2. Ability to pursue advanced studies and research in Statistics, Data Science, Biostatistics, Actuarial Science and related interdisciplinary fields.
3. Ability to apply statistical knowledge and quantitative techniques to real-world problems in science, industry, business, healthcare and social sciences.
4. Equipped with the skills and knowledge required for careers in research, teaching, data analytics, quality control, banking, insurance, healthcare, government organizations and information technology sectors.
5. Develop critical thinking, analytical reasoning and problem-solving abilities for interpreting data and making evidence-based decisions.
6. Develop computational and statistical software skills using tools such as R, Python, Excel or other analytical platforms.

7. Ability to design experiments, conduct surveys, analyze data and interpret statistical results scientifically and ethically.

Program Specific Outcomes:

1. A student should be able to recall and understand the basic concepts, definitions, terminologies, notations and methods used in Statistics.
2. Enabling students to develop a positive attitude towards Statistics as an interesting and practically useful discipline.
3. Apply statistical techniques for data collection, classification, analysis, interpretation and presentation of data.
4. Formulate statistical models and apply appropriate methods for solving theoretical and applied statistical problems.
5. Utilize statistical and computational tools for data analysis, visualization and interpretation in various real-life situations.
6. Develop the ability to conduct independent statistical investigations, surveys and research studies.
7. Develop a strong foundation in core areas of Statistics such as probability theory, sampling, statistical inference, regression analysis, multivariate analysis and operations research.
8. Understand the applications of Statistics in interdisciplinary fields including economics, healthcare, agriculture, industry, artificial intelligence and machine learning.
9. Develop ethical understanding and professional responsibility in statistical practice, research and reporting of data.
10. Enhance communication skills for presenting statistical findings effectively through reports, graphs, tables and presentations

B.Sc. Part-III (Semester-V & VI) Statistics

Sem	Course Type	Course Title	Credits T	Credits PR	T-CA	PR-CA	T-UA	PR-UA
V	DSC1-7	Statistical Inference-I	3	2	30	20	45	30
	DSC1-8	Probability Distributions	3	2	30	20	45	30
	DSC1-9	Sampling Techniques	3	2	30	20	45	30
	DSE1-1	Cyber Security	2	1	20	10	30	15
	DSE1-2	Regression Analysis	2	1	20	10	30	15
	DSE1-3	Operations Research	2	1	20	10	30	15
	VSC3	Hands on Training Related to **DSE1-1 OR DSE1-2 OR DSE1-3**	---	2	--	20	--	30
	IKS 2	Ancient Indian Statistics	2	---	20	---	30	---
VI	DSC1-10	Statistical Inference-II	3	2	30	20	45	30
VI	DSC1-11	Probability Theory	3	2	30	20	45	30
VI	DSC1-12	Design of Experiments	3	2	30	20	45	30
VI	DSE2-3	Quality Management	2	1	20	10	30	15
VI	DSE2-4	Time Series Analysis and Reliability Theory	2	1	20	10	30	15
VI	VSC4	Hands on Training Related to DSE2-3 OR DSE2-4	---	2	--	20	--	30
VI	FP2/CEP2/ OJT1	Field Projects/Internships/ Apprenticeships/ Community Engagement Projects/On-Job Training	---	2	--	20	--	30

SEMESTER – V

(I) Theory Papers:-

Paper	Course Title	Marks
DSC1-7	Statistical Inference-I	45 + 30 = 75
DSC1-8	Probability Distributions	45 + 30 = 75
DSC1-9	Sampling Techniques	45 + 30 = 75
DSE1-1	Cyber Security	30 + 20 = 50
DSE1-2	Regression Analysis	30 + 20 = 50
DSE1-3	Operations Research	30 + 20 = 50
VSC3	Hands on Training Related to DSE1-1 OR DSE1-2	30 + 20 = 50
SEC3	Data analysis using MS-EXCEL	30 + 20 = 50

SEMESTER – VI

(II) Theory Papers:-

Paper	Course Title	Marks
DSC1-10	Statistical Inference-II	45 + 30 = 75
DSC1-11	Probability Theory	45 + 30 = 75
DSC1-12	Design of Experiments	45 + 30 = 75
DSE2-3	Quality Management	30 + 20 = 50
DSE2-4	Time Series Analysis and Reliability Theory	30 + 20 = 50
VSC4	Hands on Training Related to DSE1-3 OR DSE1-4	30 + 20 = 50
FP2/CEP2/OJT1	Field Projects/Internships/ Apprenticeships/ Community Engagement Projects/On-Job Training	30 + 20 = 50

Equivalent Subject for Old Syllabus

Semester-V

Sr. No.	Name of the Old Paper	Name of the New Paper (As per NEP2020)
1	Paper-IX : Statistical Inference-I	DSC1-7: Statistical Inference-I
2	Paper-X : Probability Distributions	DSC1-8: Probability Distributions
3	Paper-XI : Sampling Techniques	DSC1-9: Sampling Techniques
		DSE1-1: Cyber Security
4	Paper-XII : Operations Research (Elective-A)	DSE1-2: Operations Research
	Paper-XII : Regression Analysis (Elective-B)	DSE1-3: Regression Analysis
5	---	VSC3: Hands on Training Related to DSE1-1 OR DSE1-2
6	---	SEC3: MS-EXCEL

Semester-VI

Sr. No.	Name of the Old Paper	Name of the New Paper (As per NEP2020)
1	Paper-XIII : Statistical Inference-II	DSC1-10: Statistical Inference-II
2	Paper-XIV : Probability Theory	DSC1-11: Probability Theory
3	Paper-XV : Design of Experiments	DSC1-12: Design of Experiments
4	Paper-XVI : Quality Management (Elective-A)	DSE2-3: Quality Management
	Paper-XVI : Time Series Analysis and Reliability Theory (Elective-B)	DSE1-4: Time Series Analysis and Reliability Theory
5	---	VSC4: Hands on Training Related to DSE2-3 OR DSE2-4
6	---	Field Projects/Internships/ Apprenticeships/ Community Engagement Projects/On-Job Training

Statistics Practical

Semester-V

Practical No.	Title	Marks
Practical-7	Practical based on DSC1-7 (Statistical Inference-I)	30 + 20 = 50
Practical-8	Practical based on DSC1-8 (Probability Distributions)	30 + 20 = 50
Practical-9	Practical based on DSC1-9 (Sampling Techniques)	30 + 20 = 50
Practical-10	Practical based on DSE1-1 (Cyber Security)	30 + 20 = 50
	Practical based on DSE1-2 (Operations Research)	30 + 20 = 50
	Practical based on DSE1-3 (Regression Analysis)	30 + 20 = 50
Practical-11	Practical based on VSC3-1 (Operations Research)	30 + 20 = 50
	Practical based on VSC3-2 (Regression Analysis)	30 + 20 = 50

Semester-VI

Practical No.	Title	Marks
Practical-12	Practical based on DSC1-10 (Statistical Inference-II)	30 + 20 = 50
Practical-13	Practical based on DSC1-11 (Probability Theory)	30 + 20 = 50
Practical-14	Practical based on DSC1-12 (Design of Experiments)	30 + 20 = 50
Practical-15	Practical based on DSE2-3 (Quality Management)	30 + 20 = 50
	Practical based on DSE2-4 (Time Series Analysis and Reliability Theory)	30 + 20 = 50
Practical-16	Practical based on VSC4-1 (Quality Management)	30 + 20 = 50
	Practical based on VSC4-2 (Time Series Analysis and Reliability Theory)	30 + 20 = 50

Numerical Technique Laboratory (NTL)
B.Sc. III Semester - V & VI

OLD ANNUAL PATTERN

NTL No.	Topic	Marks
NTL-III (A)	S-I : Statistical Inference-I [6] S-II : Statistical Inference-II [6] + Seminar	80 + 20 = 100
NTL-III (B)	S-I : Probability Distributions [6] S-II : Probability Theory [6] + Project	80 + 20 = 100
NTL-III (C)	S-I : Sampling Techniques [6] S-II : Design of Experiments [6] + Study Tour/Book Review	80 + 20 = 100
NTL-III (D)	S-I : Operations Research [6] OR S-I : Regression Analysis [6]	80 + 20 = 100
	S-II : Quality Management [6] OR S-II : Time Series Analysis and Reliability Theory [6] + Viva Voce	80 + 20 = 100

Semester-V

Paper Name: Statistical Inference-I	Course Code:
Paper Number: DSC1-7	Credits: 03

Course Objectives:

To learn about:

1. To develop conceptual understanding of statistical methods, probability theory and inferential techniques required for scientific data analysis and decision making.
2. To understand the fundamental principles of statistical inference, probability distributions and sampling techniques along with their practical applications in real-life situations.
3. To apply statistical methods for analyzing, interpreting and presenting data using mathematical and computational approaches.
4. To understand the role of statistical models in research, industry, healthcare, economics and data science.

Unit	Content	Hours
I	**Unit-1: Point Estimation:** **1.1 :** Notion of a parameter, parameter space, general problem of estimation, estimating an unknown parameter by point and interval estimation. **1.2** : Point estimation: Definition of an estimator (statistic) & its S.E., distinction between estimator and estimate, Illustrative examples. **1.3 :** Properties of estimator: Unbiased estimator, biased estimator, positive and negative bias, examples of unbiased and biased estimators. Proofs of the following results regarding the unbiased estimators: (a) Two distinct unbiased estimators of $\varphi(\theta)$ give rise to infinitely many unbiased estimators of $\varphi(\theta)$. (b) If T is unbiased estimator of θ then $\varphi(T)$ is an unbiased estimator of $\varphi(\theta)$ provided $\varphi(.)$ is a linear function. (c) Sample variance is a biased estimator of the population variance. Illustration of unbiased estimator for the parameter and parametric function. **1.4 :** Relative efficiency of T1 with respect to T2, where T1 and T2 are unbiased estimators. Use of mean square error to modify the above definition for biased estimator. Minimum Variance Unbiased Estimator (MVUE) and Uniformly Minimum Variance Unbiased Estimator (UMVUE), uniqueness of UMVUE whenever it exists. Illustrative examples. **1.5 :** Consistency: Definition, proof of the following: (a) Sufficient condition for consistency, (b) If T is consistent for θ and $\varphi(.)$ is a continuous function then $\varphi(T)$ is consistent for $\varphi(\theta)$. Numerical Case Studies	15
II	**Unit-2: Likelihood and Sufficiency (12)** **2.1:** Definition of likelihood function as a function of the parameter θ for a random sample from discrete and continuous distributions. Illustrative examples.	12

	2.2: Sufficiency: Concept of sufficiency, definition of sufficient statistic through conditional distribution and Neyman factorization criterion. Pitman - Koopman form and sufficient statistic. Proof of the following properties of sufficient statistic: (a) If T is sufficient for θ then $\varphi(T)$ is also sufficient for θ provided $\varphi(.)$ is a one-to-one and on-to function. (b) If T is sufficient for θ then T is sufficient for $\varphi(\theta)$. **2.3:** Fisher information function: Definition of information function, amount of information contained in a sample. Statement regarding equality of the information in $(x_1,x_2,.....,x_n)$ and in a sufficient statistic T, concept of minimal sufficient statistic with illustrations to exponential family. **2.4:** Numerical Case Studies.	
III	**Unit-3: Cramer – Rao inequality (7)** Statement and proof of Cramer – Rao inequality. Definition of Minimum Variance Bound Unbiased Estimator (MVBUE) of $\varphi(\theta)$. Proof of the following results: (i) If MVBUE exists for θ then MVBUE exists for $\varphi(\theta)$, if $\varphi(.)$ is a linear function. (ii) If T is MVBUE for θ then T is sufficient for θ. (iii) Numerical Case Studies.	7
IV	**Unit-4: Methods of Estimation (11)** **4.1:** Method of maximum likelihood, derivation of maximum likelihood estimators for parameters of standard distributions. Use of iterative procedure to derive MLE of location parameter μ of Cauchy distribution, invariance property of MLE, relation between MLE and sufficient statistic. Illustrative examples. **4.2:** Method of moments: Derivation of moment estimators for standard distributions. Illustrations of situations. Where MLE and moment estimators are distinct and their comparison using mean square error (for uniform distribution). Illustrative examples. **4.3:** Method of minimum chi-square: Definition, derivation of minimum chi-square estimator for the parameter. Numerical Case Studies.	11

Course Outcomes: The students will able to understand

a) Importance and application of inferential aspect of point estimation.

b) Concept of various important properties of estimator.

c) Concept and application of Fisher information and CR inequality.

Recommended Book:

- Kale, B. K.: A first Course on Parametric Inference
- Rohatgi, V. K.: Statistical Inference
- Rohatgi, V. K.: An introduction to Probability Theory and Mathematical Statistics
- Saxena H. C. and Surenderan: Statistical Inference

Reference Books:

- Kendall M. G. and Stuart A.: An advanced Theory of Statistics
- Lindgren, B. W.: Statistical Theory
- Lehmann, E. L.: Theory of Point Estimation
- Rao C.R.: Linear Statistical Inference
- Dudewicz C.J. and Mishra S.N.: Modern Mathematical Statistics
- Fergusson T.S.: Mathematical statistics.
- Zacks S.: Theory of Statistical Inference.
- Cramer H.: Mathematical Methods of Statistics.
- Cassela G. and Berger R.L.: Statistical Inference.
- Siegel, S.: Non-parametric Methods for the Behavioral Sciences.

Paper Name: Statistical Inference-I	Course Code:
Paper Number: DSC1-7 (P)	Credits: 02

Course Objectives:

To learn about to:

- **Fundamental Understanding:** Understand basic concepts of statistical inference including parameter, estimator, likelihood, sufficiency, and information measures.
- **Theoretical Knowledge:** Develop understanding of properties of estimators such as unbiasedness, consistency, efficiency, MVUE, UMVUE, and MVBUE.
- **Analytical Skills:** Apply statistical reasoning to derive and prove theoretical results including Cramer–Rao inequality and sufficiency properties.
- **Computational Techniques:** Learn methods of estimation including Method of Moments, Maximum Likelihood Estimation, and Minimum Chi-square Estimation.

Expt. No.	Title	Hours
1	Estimation of population mean and variance using sample data	4
2	Computation of biased and unbiased estimators	4
3	Verification of properties of unbiased estimators using numerical examples	4
4	Calculation of Mean Square Error (MSE) for estimators	4
5	Comparison of estimators based on relative efficiency	4
6	Study of consistency of estimators using simulated/random samples	4
7	Construction and plotting of likelihood functions for discrete distributions	4
8	Construction and plotting of likelihood functions for continuous distributions	4
9	Determination of sufficient statistics using Neyman Factorization Theorem	4
10	Calculation of Fisher Information for standard distributions	4
11	Verification of Cramer–Rao Lower Bound for selected distributions	4
12	Estimation of parameters using Method of Moments	4
13	Estimation of parameters using Maximum Likelihood Method	4
14	Estimation of parameters using Minimum Chi-square Method	4
15	Comparative study of MLE and Method of Moments estimators using numerical case studies and statistical software	4

Course Outcomes:

After Completing this course, Students will be able to:

1. Define and explain fundamental concepts of statistical inference including parameter, estimator, likelihood function, sufficiency, and Fisher information.

2. Analyze and compare properties of estimators such as unbiasedness, consistency, efficiency, MVUE, UMVUE, and MVBUE.
3. Apply methods of estimation including Method of Moments, Maximum Likelihood Estimation, and Minimum Chi-square Estimation to standard probability distributions.
4. Solve statistical inference problems using likelihood methods, sufficient statistics, and Cramer–Rao inequality.
5. Develop analytical and computational skills for practical data analysis, numerical case studies, and research-oriented statistical applications.

Paper Name: Probability Distributions	Course Code:
Paper Number: DSC1-8	Credits: 03

Course Objectives:

To learn about to:

- **Univariate Distributions:** Understand the properties and applications of Laplace, Cauchy, Lognormal, Weibull, Logistic, Pareto, and Power Series distributions.
- **Bivariate Distribution:** Understand the concept and applications of Bivariate Normal Distribution.
- **Truncated Distributions:** Learn the concept, properties, and applications of truncated distributions.
- **Application Skills:** Apply distribution theory to statistical analysis, real-life data problems, and research applications.

Unit	Content	Hours
I	**Univariate Continuous Probability Distributions** **Laplace (Double Exponential) Distribution:** P.d.f. with parameters (μ, λ), Nature of the probability curve, Distribution function, quartiles, m.g.f., mean, variance, moments,β1, β2, γ1and γ2, Laplace distribution as the distribution of the difference of two i.i.d. exponential variables with parameter θ, examples and problems. **1.2 Lognormal Distribution:** P.d.f. with parameters (μ, σ2), Nature of the probability curve, mean, variance, median, mode, moments, β1, β2, γ1and γ2coefficients, Relation with N(μ,σ2), examples and problems. **1.3 Cauchy Distribution:** P.d.f. with parameters (μ, λ), nature of the probability curve, distribution function, quartiles, non-existence of moments, additive property for two independent Cauchy variables (statement only), statement of distribution of the sample mean, relationship with uniform and Students 't' distribution, distribution of where X and Y are i. i. d. N(0,1), examples and problems. **1.4 Weibull Distribution**: p.d.f. with parameters (α, β), distribution function, quartiles, mean and variance, coefficient of variation, relation with gamma and exponential distribution, examples and problems.	15
II	**Univariate and Multivariate Probability Distributions** **2.1 Logistic distribution:** p.d.f. with parameters (μ, σ), c.d.f., mean, mode, variance, skewness using mode, applications. **2.2 Pareto distribution**: p. d .f. with parameters (α, β), mean, variance, mode, skewness using mode, applications. **2.3 Power series distribution**: p.m.f. mean, mode, variance, Binomial, Poisson, Geometric and negative binomial distribution as particular cases of power series distribution.	12
III	**Truncated Distributions:**	08

	3.1 Truncated distribution as conditional distribution, truncation to the right, left and on both sides. **3.2** Binomial distribution B (n, p) left truncated at X=0 (value zero not observable),its p.m.f, mean, variance. **3.3** Poisson distribution P(m), left truncated at X=0 (value zero not observable), its p.m.f., mean and variance. **3.4** Normal distribution N(μ,σ2) truncated i) to the left below a, ii) to the right above b, iii) to the left below a and to the right above b, its p.d.f. and mean. **3.5** Exponential distribution with parameter θ left truncated below a, its p.d.f., mean and variance. **3.6** Examples and problems	
IV	**Bivariate Normal Distribution:** **4.1** P.d.f. of a bivariate normal distribution, BN(μ1, μ 2, σ 12, σ 22, ρ) , Marginal and conditional distributions, identification of parameters, conditional expectation and conditional variance, regression of Y on X and of X on Y., independence and uncorrelatedness imply each other, m.g.f and moments. Distribution of aX+bY+c, where a,b and c are real numbers. **4.2** Cauchy distribution as the distribution of Z=X/Y where, (X,Y)~BN (0,0, σ 12, σ 22, ρ) **4.3** Examples and problems.	10

Course Outcomes:

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

- Explain the properties and applications of important univariate probability distributions such as Laplace, Lognormal, Cauchy, Weibull, Logistic, Pareto, and Power Series distributions.
- Apply concepts of truncated distributions and derive related probability functions, mean, and variance.
- Understand and analyze Bivariate Normal Distribution, including marginal and conditional distributions, regression, and correlation.
- Solve numerical and applied problems related to probability distributions and statistical modeling.

Recommended Book:

- Cramer H.: Mathematical Methods of Statistics, Asia Publishing House, Mumbai.
- 2. Mood A.M., GraybillK, Bose.D.C.: Introduction to Theory of Statistics.(Third edition) Mc-Graw Hiil Series.
- 3. Lindgren B. W.: Statistical Theory (Third Edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York.

- 4. Hogg, R.V. and Craig A.T.: Introduction to Mathematical Statistics(Third Edition), Macmillan Publishing Company,Inc.866,34dAvenue,NewYork,10022.

Reference Books:

- Sanjay Arora and Bansi Lal: New Mathematical Statistics (First Edition), Satya Prakashan, 16/17698,New Market,NewDelhi,5(1989).
- Gupta S.C and Kapoor V.K .:Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi.
- Rohatgi V.K.: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd. ,NewDelhi.
- Feller.W.: An Introduction of Probability Theory and its Applications, Wiley Eastern Ltd. Mumbai.
- Jhonson and Kotz: Continuous Univariate Distributions I and II: Discrete Distributions: Multivariate Distributions
- Bhat B.R.: Modern Probability Theory. New Age International.

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Paper Name: Probability Distributions	Course Code:
Paper Number: DSC1-8 (P)	Credits: 02

Course Objectives:

To learn about to:

- **Distribution Analysis:** Understand and compute probabilities, moments, and characteristics of various Univariate probability distributions.
- **Statistical Computation:** Develop computational skills for evaluating distribution functions, parameters, and related measures.
- **Truncated and Bivariate Models:** Apply concepts of truncated distributions and bivariate normal distribution in practical problems.
- **Application Skills:** Use statistical software and numerical methods for solving real-life problems based on probability distributions.

Expt. No.	Title	Hours
1	Numerical problems based on Laplace distribution	4
2	Numerical problems based on Lognormal distribution	4
3	Numerical problems based on Cauchy distribution	4
4	Numerical problems based on Weibull distribution	4
5	Numerical problems based on Logistic distribution	4
6	Numerical problems based on Pareto distribution	4
7	Numerical problems based on Power Series distributions	4
8	Numerical problems based on Binomial, Poisson and Geometric distributions as Power Series distributions	4
9	Numerical problems based on truncated Binomial distribution	4
10	Numerical problems based on truncated Poisson distribution	4
11	Numerical problems based on truncated Normal distribution	4
12	Numerical problems based on truncated Exponential distribution	4
13	Numerical problems based on Bivariate Normal distribution	4
14	Numerical problems based on marginal and conditional distributions	4
15	Revision on expts-1 – 14	4

Course Outcomes:

After Successful completion of the course, Students will be able to:

- Explain the properties and applications of important univariate probability distributions.
- Apply concepts of truncated distributions and compute related statistical measures.
- Analyze Bivariate Normal Distribution, marginal and conditional distributions, regression, and correlation.
- Solve practical and numerical problems related to probability distributions and statistical modeling.

Paper Name: Sampling Techniques	Course Code:
Paper Number: DSC1-9	Credits: 03

Course Objectives:

To learn about to:

- **Sampling Methods:** Understand fundamental concepts and various techniques of sampling used in statistical investigations.
- **Survey Design:** Learn methods of designing surveys, sample selection, and estimation procedures.
- **Statistical Analysis:** Develop skills in analyzing sampling errors, biases, and efficiency of sampling methods.
- **Application Skills:** Apply sampling techniques to real-life data collection, research studies, and statistical decision-making.

Unit	Content	Hours
I	**Basic Terminology and Simple Random Sampling:** **Basic Terminology:** Concept of distinguishable elementary units, sampling units, sampling frame, random sampling and non-random sampling. Advantages of sampling method over census method, objectives of a sample survey, designing a questionnaire, Characteristics of a good questionnaire, Concept of sampling and non-sampling errors. Handling of non-response cases. **1.2: Simple random sampling for attributes:** i. Sampling for dichotomous attributes. Estimation of population proportion, Sample proportion (p) as an estimator of population proportion (P), derivation of its expectation, standard error and estimator of standard error using SRSWOR. ii. Np as an estimator of total number of units in the population possessing the attribute of interest, derivation of its expectation, standard error and estimator of standard error. **1.3: Determination of the sample size:** Determination of the sample size (n) for the given: i. Margin of error and confidence coefficient ii. Coefficient of variation of the estimator and confidence coefficient.	15
II	**Stratified Sampling:** i. Real life situations where stratification can be used. ii. Description of stratified sampling method where sample is drawn from individual stratum using SRSWOR method. iii. (a) as an estimator of population mean ,derivation of its expectation, standard error and estimator of standard error. (b) N as an estimator of population total, derivation of its expectation, standard error and estimator of standard error.	15

	iv. Problem of allocation: Proportional allocation, Neyman's allocation and optimum allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used. v. Comparison amongst SRSWOR, stratification with proportional allocation and stratification with optimum allocation vi. Cost and variance analysis in stratified random sampling, minimization of variance for fixed cost, minimization of cost for fixed variance, optimum allocation as a particular case of optimization in cost and variance analysis.	
III	**Other Sampling Methods:** **3.1: Systematic Sampling:** i. Real life situations where systematic sampling is appropriate. Technique of drawing a sample using systematic sampling. ii. Estimation of population mean and population total, standard error of these estimators. iii. Comparison of systematic sampling with SRSWOR. iv. Comparison of systematic sampling with SRSWOR and stratified sampling in the presence of linear trend. v. Idea of Circular Systematic Sampling. **3.2: Cluster Sampling** i. Real life situations where cluster sampling is appropriate. Technique of drawing sample using cluster sampling. ii. Estimation of population mean and population total (with equal size clusters), standard error of these estimators. iii. Systematic sampling as a particular case of cluster sampling. **3.3: Two Stage and Multi Stage Sampling** Idea of two-stage and multi stage sampling.	05
IV	**Sampling Methods using Auxiliary variables:** **4.1: Ratio Method:** i. Concept of auxiliary variable and its use in estimation ii. Situations where Ratio method is appropriate. ii. Ratio estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors. iii. Relative efficiency of ratio estimators with that of SRSWOR. **4.2: Regression Method** i. Situations where Regression method is appropriate. ii. Regression estimators of the population mean and population total and their standard errors (without derivations), estimators of these standard errors. iii. Comments regarding bias in estimation iv. Relative efficiency of regression estimators with that of a) SRSWOR, b) Ratio estimator.	10

Course Outcomes:

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

- Explain fundamental concepts and methods of sampling techniques.
- Apply appropriate sampling methods for statistical surveys and research studies.
- Analyze sampling errors, biases, and efficiency of estimators.
- Solve practical problems related to sample surveys and data collection.

Recommended Book:

- Cochran, W.G: Sampling Techniques, Wiley Eastern Ltd., New Delhi.
- Sukhatme, P.V. and Sukhatme, B.V.: Sampling Theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.
- DesRaj: Sampling Theory.
- Daroga Singh and Choudhary F.S. : Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.

Reference Books:

- Murthy, M.N: Sampling Methods, Indian Statistical Institute, Kolkata.
- Mukhopadhay Parimal: Theory and Methods of Survey Sampling, Prentice Hall.

Paper Name: Sampling Techniques	**Course Code:**
Paper Number: DSC1-9(P)	**Credits: 02**

Course Objectives:

To learn about to:

- **Practical Sampling Methods:** Understand and perform different sampling techniques used in statistical investigations.
- **Data Collection Skills:** Develop skills in survey planning, sample selection, and data collection procedures.
- **Statistical Computation:** Apply methods for estimation, sampling error calculation, and analysis of sample data.
- **Software and Applications:** Use statistical tools/software for practical implementation of sampling techniques and survey analysis.

Expt. No.	Title	Hours
1	Study of basic terminology in sampling techniques and survey methods	4
2	Designing and preparation of a questionnaire for sample survey	4
3	Numerical problems based on estimation of population proportion using SRSWOR	4
4	Numerical problems based on estimation of population total for attributes	4
5	Determination of sample size for given margin of error and confidence coefficient	4
6	Numerical problems based on stratified random sampling	4
7	Estimation of population mean and total in stratified sampling	4
8	Numerical problems based on proportional and Neyman allocation	4

9	Cost and variance analysis in stratified random sampling	4
10	Numerical problems based on systematic sampling	4
11	Estimation of population mean and total using systematic sampling	4
12	Numerical problems based on cluster sampling	4
13	Study of two-stage and multi-stage sampling methods	4
14	Numerical problems based on ratio and regression estimation methods	4
15	Comparative study of SRSWOR, stratified, systematic, ratio and regression methods	4

Course Outcomes:

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

- Apply different sampling techniques for data collection and sample surveys.
- Estimate population parameters using simple random, stratified, systematic, and cluster sampling methods.
- Analyze sampling errors, allocation methods, and efficiency of estimators.
- Use ratio and regression methods for improved estimation in practical survey problems.

Paper Name: Cyber Security	Course Code:
Paper Number: DSE1-1	Credits: 02

Course Objectives:

To learn about to:

- Develop foundational knowledge of cyberspace, web architecture, and digital communication systems while understanding the emerging challenges in cyber security.
- Identify and analyze various forms of cyber crimes including social engineering, financial fraud, and cyber threats targeting individuals and organizations, along with relevant legal frameworks such as the IT Act 2000.
- Understand and evaluate the role of cyber law, privacy regulations, and policy mechanisms in combating cybercrime and ensuring digital safety.
- Examine the security implications of social media usage, including data privacy, inappropriate content, and legal consequences, while adopting best practices for secure digital communication.
- Explore the concepts of e-commerce and digital payment systems, including different modes of transactions, threats, and RBI guidelines for secure financial operations.
- Learn the principles of digital device security and gain hands-on skills in configuring antivirus, firewalls, password policies, and mobile device security.
- Acquire the ability to use practical tools and techniques to report, prevent, and mitigate cyber incidents, and foster a responsible and ethical approach to personal and professional digital interactions.

Unit	Content	Hours
I	**Introduction to Cyber security:** **Module Content** - Defining Cyberspace and Overview of Computer and Web-technology, Architecture of cyberspace, Communication and web, Internet, World wide web, Advent of internet, Internet infrastructure for data transfer and governance, Internet society, Regulation of cyberspace, Concept of cyber security, Issues and challenges of cyber security.	10
II	**Cybercrime and Cyber law:** **Module Content** - Classification of cyber crimes, Common cyber crimes- cyber crime targeting computers and mobiles, cyber crime against women and children, financial frauds, social engineering attacks, malware and ransomware attacks, zero day and zero click attacks, Cybercriminals modus-operandi ,Reporting of cyber crimes, Remedial and mitigation measures, Legal perspective of cyber crime, IT Act 2000 and its amendments, Cyber crime and offences, Organisations dealing with Cyber crime and Cyber security in India, Case studies.	10
III	**Social Media Overview and Security:** **Module Content -** Introduction to Social networks. Types of Social media, Social media platforms, Social media monitoring, Hashtag, Viral content, Social media marketing, Social media privacy, Challenges, opportunities and pitfalls in online social network, Security issues related to social media, Flagging and reporting of inappropriate content, Laws	10

	regarding posting of inappropriate content, Best practices for the use of Social media, Case studies.	
IV	**E - Commerce and Digital Payments:** **Module Content -** Definition of E- Commerce, Main components of E-Commerce, Elements of E-Commerce security, E-Commerce threats, E-Commerce security best practices, Introduction to digital payments, Components of digital payment and stake holders, Modes of digital payments- Banking Cards, Unified Payment Interface (UPI), e-Wallets, Unstructured Supplementary Service Data (USSD), Aadhar enabled payments, Digital payments related common frauds and preventive measures. RBI guidelines on digital payments and customer protection in unauthorised banking transactions. Relevant provisions of Payment Settlement Act,2007	10
V	**Digital Devices Security, Tools and Technologies for Cyber Security:** **Module Content -** End Point device and Mobile phone security, Password policy, Security patch management, Data backup, Downloading and management of third party software, Device security policy, Cyber Security best practices, Significance of host firewall and Ant-virus, Management of host firewall and Anti-virus, Wi-Fi security, Configuration of basic security policy and permissions.	10

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

- Understand cyber crimes, legal remedies, and reporting procedures.
- Identify privacy and security issues related to social media and online platforms.
- Explain concepts of E-Commerce, digital payments, and cyber security measures.
- Apply basic security tools and practices for protection of computers and mobile devices.

Recommended Book:

1. Cyber Crime Impact in the New Millennium, by R. C Mishra, Auther Press. Edition 2010.
2. Cyber Security Understanding Cyber Crimes, Computer Forensics and Legal Perspectives by Sumit Belapure and Nina Godbole, Wiley India Pvt. Ltd. (First Edition, 2011)
3. Security in the Digital Age: Social Media Security Threats and Vulnerabilities by Henry A. Oliver, Create Space Independent Publishing Platform. (Pearson , 13th November, 2001)
4. Electronic Commerce by Elias M. Awad, Prentice Hall of India Pvt Ltd.

Reference Books:

5. Cyber Laws: Intellectual Property & E-Commerce Security by Kumar K, Dominant Publishers.
6. Network Security Bible, Eric Cole, Ronald Krutz, James W. Conley, 2nd Edition, Wiley India Pvt. Ltd.
7. Fundamentals of Network Security by E. Maiwald, McGraw Hill.

Paper Name: Cyber Security	Course Code:
Paper Number: DSE1-1(P) / VSC3	Credits: 01

Course Objectives:

To learn about to:

- Basic concepts of cyber security, phishing attacks, and email security practices.
- Privacy settings, reporting mechanisms, and safe use of social media platforms.
- Secure digital payment methods and preventive measures against online frauds.
- Security tools and techniques for protecting computers, operating systems, and mobile devices.

Expt. No.	Title	Hours
1	**Lab 1: Phishing Awareness and Email Security** Experiments • Identifying phishing emails • Reporting phishing attempts • Demonstration of phishing attack lifecycle • Email header analysis • Anti-phishing best practices	4
2	**Lab 2: Social Media Privacy and Reporting** Experiments • Privacy configuration on social platforms • Reporting inappropriate content • Identifying fake profiles • Detecting misinformation • Digital footprint analysis	4
3	**Lab 3: Digital Payment Security** Experiments • Secure configuration of UPI applications • Mobile wallet security settings • Identifying digital payment fraud patterns • Transaction verification mechanisms • RBI consumer complaint portals	4
4	**Lab 4: Operating System Security Basics** Experiments • User account management • Password policy implementation • BIOS password configuration • Standard vs administrator privileges • File encryption basics	4
5	**Lab 5: System Security Tools** Experiments • Installing and configuring antivirus software • Firewall configuration • Malware scanning and removal	4

	• System update and patch management • Disk backup and recovery tools	
6	**Lab 6: Mobile Security and Permissions** Experiments • Mobile application permission management • Detecting malicious apps • Secure device configuration • Mobile OS security settings	4

Course Outcomes:

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

- Identify phishing attempts, email threats, and apply safe online communication practices.
- Configure privacy settings and report inappropriate or suspicious activities on social media.
- Use secure digital payment methods and recognize common cyber fraud patterns.
- Apply basic security tools and practices to protect computer systems and mobile devices.

Recommended Book:

- Cyber Crime Impact in the New Millennium, by R. C Mishra, Auther Press. Edition
- 2010.
- Cyber Security Understanding Cyber Crimes, Computer Forensics and Legal
- Perspectives by Sumit Belapure and Nina Godbole, Wiley India Pvt. Ltd. (First
- Edition, 2011)
- Security in the Digital Age: Social Media Security Threats and Vulnerabilities by
- Henry A. Oliver, Create Space Independent Publishing Platform. (Pearson , 13th
- November, 2001)
- Electronic Commerce by Elias M. Awad, Prentice Hall of India Pvt Ltd.

Reference Books:

- Cyber Laws: Intellectual Property & E-Commerce Security by Kumar K, Dominant
- Publishers.
- Network Security Bible, Eric Cole, Ronald Krutz, James W. Conley, 2nd Edition,
- Wiley India Pvt. Ltd.
- Fundamentals of Network Security by E. Maiwald, McGraw Hill.

Paper Name: Regression Analysis	Course Code:
Paper Number: DSE1-2	Credits: 02

Course Objectives:
To learn about to:

- Fundamental concepts and methods of regression analysis.
- Techniques for fitting and interpreting simple and multiple regression models.
- Methods for testing significance, prediction, and model adequacy.
- Applications of regression analysis in statistical research and real-life data analysis.

Unit	Content	Hours
I	**Simple linear regression model:** 1.1. Review of Simple Linear Regression Model: Simple linear regression model $Y=\beta 0+\beta 1X+\varepsilon$ where ε is a continuous random variable with $E(\varepsilon)=0,\ V(\varepsilon)=\sigma^2$ 1.2. Estimation of Regression Parameters: Estimation of β_0 and β_1 by the method of least squares, properties of estimators of β_0 and β_1, estimation of σ^2, assumption of normality of ε, tests of hypothesis for regression coefficients, interval estimation in simple regression model, coefficient of determination. 1.3. Residual Analysis: Standardized residuals, Studentized residuals, residual plots, detection and treatment of outliers.	10
II	**Review of multiple Regression Model:** 2.1: Review of Multiple Linear Regression Model: Multiple linear regression model $Y=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta pXp+\varepsilon$ where ε is a continuous random variable with $E(\varepsilon)=0,\ V(\varepsilon)=\sigma^2$ 2.2 Estimation of Regression Parameters: Estimation of regression parameters $\beta_0, \beta_1, \ldots, \beta_p$ by the method of least squares, obtaining normal equations, estimation of σ^2, assumption of normality of ε, tests of hypothesis for regression parameters. 2.3 Model Building and Diagnostics: Variable selection and model building, residual diagnostics, and corrective measures such as transformation of response variable and weighted least squares method.	10
III	**Logistic Regression Model:** Binary response variable, logit transform estimation and interpretation of parameters. Tests of hypotheses of model parameters, model deviance, LR test.	10

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

- Explain concepts and assumptions of regression analysis.
- Fit and interpret simple and multiple regression models.
- Perform prediction, hypothesis testing, and model evaluation.
- Apply regression techniques to practical data analysis and research problems.

Recommended Book:

- Montgomery D.C., Peak E.A., and Vining G.G. (2003). Introduction to Linear Regression Analysis (Wiley)
- Hosmer D.W. And Lemeshow, S. (1989). Applied Logistic Regression (Wiley)

Reference Books:

- Manisha Sane, Regression Analysis: Nirali Prakashan

Paper Name: Regression Analysis	Course Code:
Paper Number: DSE1-2 (P) / VSC3	Credits: 01

Course Objectives:

To learn about to:

- Fundamental concepts and methods of regression analysis.
- Techniques for fitting and interpreting simple and multiple regression models.
- Methods for testing significance, prediction, and model adequacy.
- Applications of regression analysis in statistical research and real-life data analysis.

Expt. No.	Title	Hours
1	Numerical problems based on simple linear regression model	4
2	Estimation of regression coefficients using least squares method	4
3	Numerical problems based on hypothesis testing in simple regression	4
4	Calculation and interpretation of coefficient of determination	4
5	Residual analysis and detection of outliers	4
6	Numerical problems based on multiple linear regression model	4
7	Estimation of multiple regression parameters and normal equations	4
8	Variable selection and model building in multiple regression	4
9	Residual diagnostics and corrective measures in regression analysis	4
10	Numerical problems based on logistic regression model and interpretation of parameters	4

Course Outcomes:

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

- Explain concepts and assumptions of regression analysis.
- Fit and interpret simple and multiple regression models.
- Perform prediction, hypothesis testing, and model evaluation.
- Apply regression techniques to practical data analysis and research problems.

Recommended Book:

- Montgomery D.C., Peak E.A., and Vining G.G. (2003). Introduction to Linear Regression Analysis (Wiley)
- Hosmer D.W. And Lemeshow, S. (1989). Applied Logistic Regression (Wiley)

Reference Books:

- Manisha Sane, Regression Analysis: Nirali Prakashan

Paper Name: Operations Research	Course Code:
Paper Number: DSE1-3	Credits: 02

Course Objectives:

To learn about to:

1. Determining the best way to allocate limited, scarce resources among competing activities.
2. Assisting managers in making better, faster, and more confident decisions through quantitative, scientific analysis.
3. Identifying the best (optimum) solution to complex problems by analyzing alternative courses of action.
4. Developing models to represent real-world problems and simulate, analyze, and predict outcomes.

Unit	Content	Hours
I	**Modelling with Linear Programming:** Two variable Linear Programming Model, Solution of Linear Programming Model by Graphical Method, Applications of Linear Programming in Production Planning and Inventory Control (Single Period Production Model, Multiple Period Production Inventory Model, Multiple period Production Smoothing Model), Manpower Planning.	10
II	**Transportation and Assignment Model:** Definition of the Transportation model, The Transportation Algorithm, Determination of starting solution (Northwest-corner method, least cost method, Vogel Approximation Method(VAM)), Iterative Computations of the Transportation Algorithm, The Assignment Model, The Hungarian method, Simplex explanation of the Hungarian method).	10
III	**Games Theory:** Introduction, Some basic definitions as Saddle point, Payoff matrix, strategy, Optimal Solution of Two- person Zero Sum Game, Solution of Mixed strategy Games (Graphical Solution of games, Linear programming solution of games)	10

Course Outcomes:

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

1. Ability to formulate mathematical models (linear programming) for quantitative analysis of industrial problems.
2. Proficiency in solving transportation, assignment, and resource allocation problems to achieve optimal results.
3. Skill in applying network models (CPM and PERT) for project management and scheduling.
4. Understanding game theory and decision analysis to guide management choices.

Recommended Book:

- Hamdy A. Taha, Operation Research (9thEdition), Pearson Education Inc.

Reference Books:

- S.D. Sharma: Operation Research, kedarNath Ram Nath& Company
- Introduction to Operations Research by F.S. Hillier & G.J. Lieberman (Best for conceptual, mathematical rigor).
- Operations Research: Applications and Algorithms by Wayne L. Winston (Excellent for modeling and practical applications)
- Schaum's Outline of Operations Research by Richard Bronson (Excellent for solved problems)
- Linear Programming by V. Chvátal (Classical text on LP)
- Network Flows: Theory, Algorithms, and Applications by R.K. Ahuja, T.L. Magnanti, & J.B. Orlin.
- Applied Integer Programming: Modeling and Solution by D. Chen, R.G. Batson, & Y. Dang.
- Operations Research: A Practical Introduction by Michael W. Carter & Camille C. Price
- Operations Research by KantiSwarup, P.K. Gupta, and Man Mohan
- Operations Research: Principles and Practice by Ravindran, Phillips, and Solberg

Paper Name: Practical based on DSE1-3 (Operations Research)	Course Code:
Paper Number: DSE1-3 (P)	Credits: 01

Course Objectives:

To learn about to:

1. Provide hands-on experience in solving complex optimization problems using software tools and manual algorithms.
2. Enable interpretation of optimal solutions and conduct sensitivity analysis to understand the impact of changes in constraints or costs.
3. Apply OR techniques to practical scenarios, including production planning, inventory management, and network analysis.
4. Develop skills for optimizing resource usage, such as maximizing profit or minimizing costs/time.

Expt. No.	Title	Hours
1	Numerical problems based on two variable linear Programming Model	4
2	Numerical problems based on solution of Linear Programming Model by Graphical method	4
3	Numerical problems based on Payoff Matrix	4
4	Numerical problems based on Transportation Algorithm	4
5	Numerical problems based on Hungarian Method	4
6	Numerical problems based on Simplex explanation of the Hungarian method	4
7	Numerical problems based on Vogel Approximation	4
8	Numerical problems based on solution of Mixed strategy games	4
9	Numerical problems based on linear programming solution of games	4
10	Numerical problems based on optimal solution o two person zero sum game	4

Course Outcomes:

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

1. Ability to define, structure, and model real-world business problems into linear programming models (LPP), including identifying objective functions and constraints.
2. Proficiency in applying algorithms to solve transportation, assignment, and sequencing problems using methods like Hungarian.
3. Hands-on experience using optimization software to solve complex operational, inventory, and network problems.
4. Capability to analyze sensitivity, interpret, and report on the consequences of different scenarios for enhanced managerial decision-making.

Paper Name: Hands on Training based on DSE1-1 OR DSE1-2 OR DSE1-3	**Course Code:**
Paper Number: VSC3	**Credits: 02**

Course Objectives: To learn about to:

1. Understand concepts and applications of Regression Analysis and Operations Research.
2. Develop analytical and problem-solving skills using statistical techniques.
3. Apply optimization and regression models to real-life problems.
4. Use R/Python software for computational and practical analysis.

Expt. No.	Title of Practical / Hands on Training	Related Paper	Hours
1	Numerical problems based on simple linear regression model	DSE1-2 Regression Analysis	4
2	Estimation of regression coefficients using least squares method	DSE1-2 Regression Analysis	4
3	Numerical problems on hypothesis testing in regression	DSE1-2 Regression Analysis	4
4	Calculation and interpretation of coefficient of determination	DSE1-2 Regression Analysis	4
5	Residual analysis and detection of outliers	DSE1-2 Regression Analysis	4
6	Numerical problems on multiple linear regression model	DSE1-2 Regression Analysis	4
7	Variable selection and model building in regression	DSE1-2 Regression Analysis	4
8	Residual diagnostics and corrective measures	DSE1-2 Regression Analysis	4
9	Numerical problems on logistic regression model	DSE1-2 Regression Analysis	4
10	Applications of regression analysis using R/Python software	DSE1-2 Regression Analysis	4
11	Formulation of Linear Programming Problems (LPP)	DSE1-3 Operations Research	4
12	Solution of LPP using graphical method	DSE1-3 Operations Research	4
13	Numerical problems on transportation models	DSE1-3 Operations Research	4
14	Solution of transportation problems using North-West Corner Method	DSE1-3 Operations Research	4
15	Solution of transportation problems using Least Cost Method	DSE1-3 Operations Research	4

16	Numerical problems using Vogel Approximation Method (VAM)	DSE1-3 Operations Research	4
17	Numerical problems on assignment problems using Hungarian Method	DSE1-3 Operations Research	4
18	Numerical problems on payoff matrix and game theory	DSE1-3 Operations Research	4
19	Solution of mixed strategy games using graphical method	DSE1-3 Operations Research	4
20	Applications of Operations Research techniques using R/Python software	DSE1-3 Operations Research	4

Note : "All the above hands-on training sessions shall be conducted using R/Python programming and relevant statistical software tools."

Course outcome:

After successful competition of the course student will be able to

1. Apply regression techniques for prediction and data analysis.
2. Formulate and solve optimization problems using OR techniques.
3. Interpret statistical results for decision-making and research.
4. Use statistical software tools for practical problem solving.

Paper Name: Ancient Indian Statistics	Course Code:
Paper Number: IKS2	Credits: 02

Course Objectives:

To learn about to:

1. To know the contribution of Indian Statistics in the development of Statistics.
2. To understand various methods and concepts in Statistics in ancient India.
3. To find interlink between methods in ancient Indian Mathematics to Modern Statistics.

Unit	Content	Hours
I	**Ancient Indian Statistical Ideas and Counting Methods**	07
1.1	Early concepts of counting and data recording in Ancient India	
1.2	Enumeration methods in Vedic literature	
1.3	Census and population recording practices in ancient kingdoms	
1.4	Applications of counting techniques in trade, agriculture, and administration	
II	**Contributions of Ancient Indian Scholars**	08
2.1	Contributions of Aryabhata and Brahmagupta to mathematical calculations	
2.2	Pingala's Binary Number System and combinatorial ideas	
2.3	Ancient Indian methods of large number representation and calculations	
III	**Probability and Combinatorial Concepts in Ancient India**	08
3.1	Combinatorial ideas in Chandah-Sastra of Pingala	
3.2	Permutations and combinations in ancient Indian mathematics	
3.3	Applications of combinatorial methods in poetry and coding patterns	
IV	**Ancient Indian Applications of Statistics**	07
4.1	Statistical ideas in astronomy, trade, and taxation systems	
4.2	Use of averages and measurements in ancient Indian sciences	
4.3	Practical importance of ancient Indian mathematical and statistical knowledge	

Course Outcomes:

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

1. Students will be able to know methods and concepts in Statistics in ancient India.
2. Students will be able to find connections between methods in ancient Indian Mathematics to Modern Statistics
3. Statistical approach to find solutions to different kind problems will be developed among students.

Recommended Book:

1. Bibhutibhushan Datta and A.N. Singh, *History of Hindu Mathematics: A Source Book*
   History of Hindu Mathematics
2. Kim Plofker, *Mathematics in India: 500 BCE–1800 CE*
   Mathematics in India Book
3. C.N. Srinivasiengar, *The History of Ancient Indian Mathematics*
   The History of Ancient Indian Mathematics

Reference Books:

1. George Gheverghese Joseph, *The Crest of the Peacock: Non-European Roots of Mathematics*
   The Crest of the Peacock

2. B.S. Yadav, *Ancient Indian Leaps into Mathematics*
   Ancient Indian Leaps into Mathematics
3. I.S. Bhanu Murthy, *A Modern Introduction to Ancient Indian Mathematics*
   Probability in Ancient India PDF
4. George Gheverghese Joseph, *A Passage to Infinity: Medieval Indian Mathematics from Kerala and Its Impact*
   A Passage to Infinity
5. Bharati Krishna Tirtha, *Vedic Mathematics*
   Vedic Mathematics

SEMESTER – VI

Paper Name: Statistical Inference-II	**Course Code:**
Paper Number: DSC1-10	**Credits: 03**

Course Objectives:

The students will able to understand

1. Concept and application of interval estimation.
2. Difference between parametric and non-parametric tests.
3. Importance of sequential test procedure.

Unit	**Content**	**Hours**
I	**Interval Estimation:** **1.1** Notion of interval estimation, definition of confidence interval, length of confidence interval, confidence bounds. Definition of Pivotal quantity and its use in obtaining confidence intervals and bounds. **1.2** Interval estimation for the following cases: Mean μ of normal distribution (σ^2 known and σ^2 unknown). i. Variance σ^2 of normal distribution (μ known and μ unknown). ii. Difference between two means μ_1-μ_2, (a) for a sample from bivariate normal population, (b) for samples from two independent normal populations. iii. Ratio of variances for samples from two independent normal populations. iv. Mean of exponential distribution. v. Population proportion and difference of two population proportions of two independent large samples. vi. Population median using order statistics. Illustrative examples.	11
II	Parametric Tests **2.1:** Statistical hypothesis, problems of testing of hypothesis, definitions and illustrations of (i)simple hypothesis (ii) composite hypothesis, critical region, type I and type II error, probabilities of type I & type II errors. Power of a	13

	test, p-value, size of a test, level of significance, problem of controlling probabilities of type I& type II errors. **2.2:** Definition of Most Powerful (MP) test. Statement and proof (sufficient part) of Neyman- Pearson (NP) lemma for simple null hypothesis against simple alternative hypothesis for construction of MP test. Examples of construction of MP test of level α. **2.3:** Power function of a test, power curve, definition of uniformly most powerful (UMP) level α test. Use of NP lemma for constructing UMP level α test for one-sided alternative. Illustrative examples. **2.4:** Likelihood Ratio Test: Procedure of likelihood ratio test, statement and its properties, Likelihood Ratio test involving mean and variance of normal population.	
III	Sequential Tests: General theory of sequential analysis and its comparison with fixed sample procedure. Wald's SPRT of strength (α,β), for simple null hypothesis against simple alternative hypothesis. Illustrations for standard distributions like binomial, Poisson, exponential and normal. Graphical and tabular procedure for carrying out the test. Illustrative examples.	9
IV	Non-parametric Test: Notion of non-parametric statistical inference (test) and its comparison with parametric statistical inference. Concept of distribution free statistic. Test procedure of: i. Run test for one sample (i.e. test for randomness) and run test for two independent sample problems. ii. Sign test for one sample and two sample paired observations iii. Wilcoxon's signed rank test for one sample and two sample paired observations. iv. Mann- Whitney U- test (two independent samples) v. Median test vi. Kolmogorov Smirnov test for one and for two independent samples.	12

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

1. To find point and interval estimates of mean with variance known and unknown situation
2. Can differentiate between parametric and non-parametric tests and also apply accordingly.
3. Can understand the importance of sequential test procedure.

Recommended Book: Kale, B.K.: A first Course on Parametric Inference
Reference Books:

1. Rohatgi, V.K.: Statistical Inference
2. Rohatgi, V.K.: An introduction to Probability Theory and Mathematical Statistics
3. Saxena H.C. and Surenderan: Statistical Inference
4. Kendall M.G. and Stuart A.: An Advanced Theory of Statistics
5. Lindgren, B.W.: Statistical Theory
6. Cassela G. and Berger R. L.: Statistical Inference
7. Lehmann, E.L: Testing of Statistical Hypothesis
8. Rao, C. R.: Linear Statistical Inference
9. Dudewicz C.J. and Mishra S. N.: Modern Mathematical Statistics
10. Fergusson, T.S.: Mathematical Statistics.
11. Zacks, S.: Theory of Statistical Inference.
12. Cramer, H.: Mathematical Methods of Statistics.
13. Gibbons, J.D.: Non-parametric Statistical Inference.
14. Doniel: Applied Non-parametric Statistics
15. Siegel,S.: Non-parametric Methods for the behavioral sciences.
16. Kunte,S.; Purophit, S.G. and Wanjale, S.K.: Lecture notes on Non-parametricTests.

Paper Name: Practical based on DSC1-10 (Statistical inference)	Course Code:
Paper Number: DSC1-10(P)	Credits: 02

Course Objectives:

To learn about to:

1. Develop the ability to point estimate by various methods for discrete and continuous distributions parameters
2. Develop the ability to estimate interval for location and scale parameters
3. Develop the ability to construct MP and UMP test
4. Develop the ability to construct SPRT for discrete and continuous distributions
5. Develop parametric and non-parametric test

Expt. No.	Title	Hours
1	Point estimation by Method of Moments for discrete distributions	4
2	Point estimation by Method of Moments for continuous distributions	4
3	Point estimation by Maximum Likelihood Method (one parameter)	4
4	Point estimation by Maximum Likelihood Method (two parameters)	4
5	Point estimation by Minimum Chi-square Method	4
6	Interval estimation of location parameters of normal distribution	4
7	Interval estimation of scale parameters of normal distribution	4
8	Interval estimation for population proportion and population median	4
9	Construction of Most Powerful (MP) test	4
10	Construction of Uniformly Most Powerful (UMP) test	4
11	Construction of SPRT for Binomial and Poisson distributions	4
12	Construction of SPRT for Exponential and Normal distributions	4
13	Non-parametric tests: Run test and Sign test	4
14	Non-parametric tests: Wilcoxon signed rank test and Mann-Whitney U-test	4
15	Non-parametric tests: Median test and Kolmogorov-Smirnov test	4

Course Outcomes:

After successful completion of the practical course, :

- Students will be able to develop the ability to point estimate by various methods for discrete and continuous distributions parameters

  Students will be able to develop the ability to estimate interval for location and scale parameters
- Students will be able to develop the ability to construct MP and UMP test
- Students will be able to develop the ability to construct SPRT for discrete and continuous distributions
- Students will be able to develop parametric and non parametric test

Paper Name: Probability Theory	Course Code:
Paper Number: DSC1-11	Credits: 03

Course Objectives:

To learn about to:

a) Idea behind order statistics and its use.

b) Concept of different modes of convergence of random variables.

c) Concept and real life application of Markov chain.

Unit	Content	Hours
I	**Order Statistics:** i. Order statistics for a random sample of size n from a continuous distribution, Joint distribution, definition, derivation of distribution function and density function of the i^{th} order statistic, particular cases for i=1 and i=n. ii. Derivation of joint p.d.f. of i^{th} and j^{th} order statistics, statement of distribution of the sample range. iii. Distribution of the sample median when n is odd. iv. Examples and Problems	10
II	**Convergence and Limit Theorem:** **2.1 :Convergence:** i. Definition of convergence of sequence of random variables (a) in probability, (b)in distribution, (c)in quadratic mean. ii. If $X_n \xrightarrow{P} X$ then $g(X_n) \xrightarrow{P} g(X)$ where g(.) is continuous function (without proof.) iii. Examples and problems. **2.2 Weak Law of Large Numbers** i. Weak law of large numbers (WLLN) statement and proof for i.i.d. random variables with finite variance. ii. Simple examples based on Bernoulli, binomial, Poisson , chi-square etc distributions	15
III	**Finite Markov Chains:** **3.1 Basic concepts:** Definition and examples of stochastic process, classification of general stochastic process into discrete–continuous time, discrete –continuous state space, type of stochastic process, Examples and problems.	15

	3.2 Markov chain: Definition and examples of Markov chain, stochastic matrix, transition probability matrix, Chapman-Kolmogorov equation (statement only), n step transition probability matrix, classification of states, simple problems. Stationary probability distribution, applications. Examples and problems. **3.3 : Continuous Markov chain:** i. Pure birth process, Poisson process, birth and death process (Derivations not expected). ii. Examples and problems.	
IV	**Queuing Theory:** i. Introduction, essential features of queuing system, input source, queue configuration, queue discipline, service mechanism. ii. Operating characteristics of queuing system, transient-state and steady state, queue length, general relationship among system characteristics. iii. Probability distributions in queuing system: Distribution of arrival, distribution of inter arrival time, distribution of departure and distribution of service time (Derivations are not expected). iv. Types of queuing models. v. Solution of queuing Model: M/M/1, using FCFS queue discipline. vi. Examples and problems.	11

Course Outcomes:

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

a) Students will able to define order statistics ,idea behind order statistics and its use.

b) Students will able to demonstrate the concept of different modes of convergence of random variables.

c) Students will able to define Markov chain and also use in real life application .

Recommended Book:

Gupta S.C and Kapoor V. K.: Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi 2.

Reference Books:

1. Cramer H.: Mathematical Methods of Statistics, Asia Publishing House, Mumbai.
2. Lindgren B.W.: Statistical Theory (Third Edition), Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York.
3. Hogg, R.V. and Craig A.T.: Introduction to Mathematical Statistics (Third Edition), Macmillan Publishing Company, Inc. 866,34d Avenue, New York, 10022.

4. Sanjay Arora and Bansi Lal: New Mathematical Statistics (First Edition), Satya Prakashan 16/17698,New Market, New Delhi, 5(1989).
5. Gupta S.C and Kapoor V. K.: Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88, Daryaganj, New Delhi 2.
6. Rohatgi V.K.: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi.
7. Medhi J: Stochastic Processes. Wiley Eastern Ltd. New Delhi.
8. Hoel, Port and Stone: Introduction to Stochastic Processes, Houghton Mifflin.
9. Feller. W.: An Introduction to Probability Theory and its Applications. Wiley Eastern Ltd. Mumbai.
10. Bhat B.R.: Modern Probability Theory.
11. Karlin and Taylor: Stochastic Process.
12. Ross S: Probability Theory
13. Bhat B. R.: Stochastic Models: Analysis and Applications. New Age International.
14. Zacks S.: Introduction to Reliability Analysis, Probability Models and Statistical Methods, Springer Verlag.
15. Taha H.A.: Operation research–An Introduction, Fifth edition, Prentice Hall of India, New Delhi.
16. Barlow R. E. and Proschan Frank: Statistical Theory of Reliability and Life Testing. Holt
.Rinebart and Winston Inc., New York
17. Sinha S. K.: Reliability and Life Testing, Second Edition, Wiley Eastern Publishers, New Delhi.
18. Trivedi R. S.: Probability and Statistics with Reliability and Computer Science Application, Prentice–Hall of India Pvt .Ltd., New Delhi.
19. Parimal Mukhopadhyaya: An Introduction to the Theory of Probability. World Scientific Publishing.

Paper Name: Practical based on DSC1-11 (Probability theory)	Course Code:
Paper Number: DSC1-11(P)	Credits: 02

Course Objectives:

To learn about to:

1. Understand concepts of order statistics, convergence, Markov chains, and queuing theory.
2. Develop analytical and probabilistic problem-solving skills.
3. Apply stochastic models to real-life situations.
4. Enhance computational skills through numerical problems and applications.

Expt. No.	Title of Practical	Hours
1	Study of order statistics	4
2	Numerical problems on ith order statistic	4
3	Numerical problems on smallest and largest order statistics	4
4	Numerical problems on sample range	4
5	Numerical problems on sample median	4
6	Problems based on convergence in probability	4
7	Problems based on convergence in distribution	4
8	Problems based on convergence in quadratic mean	4
9	Problems based on Weak Law of Large Numbers (WLLN)	4
10	Study of stochastic processes and Markov chains	4
11	Numerical problems on transition probability matrix	4
12	Numerical problems on Chapman–Kolmogorov equations	4
13	Numerical problems on stationary probability distribution	4
14	Numerical problems on birth-death process	4
15	Numerical problems on queuing models and M/M/1 system	4

Course Outcomes:

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

1. Apply concepts of order statistics and convergence of random variables.
2. Analyze Weak Law of Large Numbers and stochastic processes.
3. Construct and interpret Markov chain models and stationary distributions.
4. Solve practical problems related to queuing models and service systems.

Paper Name: Designs of Experiments	Course Code:
Paper Number: DSC1-12	Credits: 03

Course Objectives:

To learn about to:

a) Basic terminology involved in designing of experiment.
b) Concept and use of different experimental designs.
c) Concept and real-life application of factorial experiment.

Course Outcomes:

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

a) Students will be able to understand basic terminology involved in designing of experiment.
b) Students will be able to use of different experimental designs.
c) Students will be able to understand the concept and real-life application of factorial experiment.

Recommended Book:

Montgomery, D.C.: Design and Analysis of Experiments, Wiley Eastern Ltd., New

Unit	Content	Hours
I	**Simple Designs of Experiments I:** **1.1 Basic Concepts:** i. Basic terms in design of experiments: Experimental unit, treatment, layout of an experiment. ii. Basic principles of design of experiments: Replication, randomization and local control. iii. Choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots. **1.2 : Completely Randomized Design (CRD)** i. Application of the principles of design of experiments in CRD, layout, model, assumptions and interpretations: ii. Estimation of parameters, expected values of mean sum of squares, components of variance. iii. Break up of total sum of squares into components. iv. Technique of one way analysis of variance (ANOVA) and it's applications to CRD. v. Testing for equality for treatment effects and it's interpretation. F-test for testing H_0, test for equality of two specified treatment effects.	10

Delhi.

Reference Books:

1. Federer, W.T.: Experimental Design, Oxford and IBH publishing Company, New Delhi.
2. Cochran, W.G. and Cox, G.M.: Experimental Design, John Wiley and Sons, Inc., New York.
3. Das, M. N. and Giri, N. C.: Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
4. Goulden, G.H.: Methods of Statistical Analysis, Asia Publishing House, Mumbai.
5. Kempthrone, O.: Design and Analysis of Experiments, Wiley Eastern Ltd., New Delhi.
6. Snedecor, G.W. and Cochran, W.G.: Statistical Methods, Affiliated East-West Press, New Delhi.
7. Goon, Gupta, Dasgupta: Fundamental of Statistics, Vol. I and II, The World Press Pvt. Ltd. Kolkata.
8. Gupta, S.C. and Kapoor, V. K.: Fundamentals of Applied Statistics, S. Chand &Sons, New Delhi.
9. C.F. Jeff Wu, Michael Hamada: Experiments, Planning Analysis and Parameter Design Optimization.

Unit	Content	Hours
II	**Simple Design of Experiments II:** **2.1 Randomized Block Design (RBD):** a) Application of the principles of design of experiments in RBD, layout, model, assumptions and interpretations: b) Estimation of parameters, expected values of mean sum of squares, components of variance. c) Breakup of total sum of squares into components. d) Technique of two way analysis of variance (ANOVA) and its applications to RBD. e)Tests and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.). f) Idea of missing plot technique. g) Situations where missing plot technique is applicable. h) Analysis of RBD with single missing observation. **2.2 Latin Square Design (LSD):** a) Application of the principles of design of experiments in LSD, layout, model, assumptions and interpretations b) Break up of total sum of squares into components c) Estimation of parameters, expected values of mean sum of squares, components of variance. Preparation of analysis of variance (ANOVA) table. d) Tests and their interpretations, test for equality of two specified treatment effects, comparison of treatment effects using critical difference (C.D.) e) Analysis of LSD with single missing observation f) Identification of real life situations where CRD, RBD and LSD are used .	15
III	**Efficiency of design and ANOCOVA:** **3.1 Efficiency of design:** i. Concept and definition of efficiency of a design. ii. Efficiency of RBD over CRD. iii. Efficiency of LSD over CRD and LSD over RBD. **3.2 Analysis of Covariance (ANOCOVA) with one concomitant variable:** i. Purpose of analysis of covariance. ii. Practical situations where analysis of covariance is applicable. iii. Model for analysis of covariance in CRD and RBD. Estimation of parameters (derivations are not expected). iv. Preparation of analysis of covariance (ANOCOVA) table, test for $\beta=0$, test for equality of treatment effects (computational technique only). **Note:** For given data, irrespective of the outcome of the	10

	test of regression coefficient (β), ANOCOVA should be carried out.	
IV	**Factorial Experiments:** i. General description of factorial experiments, 2^2 and 2^3 factorial experiments arranged in RBD. ii. Definitions of main effects and interaction effects in 2^2 and 2^3 factorial experiments. iii. Model, assumptions and its interpretation. iv. Preparation of ANOVA table by Yate's procedure, test for main effects and interaction effects. v. General idea and purpose of confounding in factorial experiments. vi. Total confounding (Confounding only one interaction): ANOVA table, testing main effects and interaction effects. vii. Partial Confounding (Confounding only one interaction per replicate): ANOVA table, testing main effects and interaction effects. viii. Construction of layout in total confounding and partial confounding in 2^3 factorial experiment.	10

Paper Name: Practical based on DSC1-12 (Design of experiments)	**Course Code:**
Paper Number: DSC1-12 (P)	**Credits: 02**

Course Objectives:

To learn about to:

1. To develop the ability to apply tools of analysis of CRD, RBD and LSD
2. To develop the ability to apply tools of analysis of CRD, RBD and LSD to missing observations
3. To develop the ability in determinations of sample size
4. To develop the ability in determinations of samples from Simple random sampling, Stratified sampling, Cluster sampling, Systemic sampling
5. To develop the ability to estimate by ratio method and regression method

Expt. No.	Title	Hours
1	Analysis of Completely Randomized Design (CRD)	4
2	Analysis of Randomized Block Design (RBD)	4
3	Analysis of Latin Square Design (LSD)	4
4	Missing Plot Technique in RBD	4
5	Missing Plot Technique in LSD	4
6	Efficiency comparison of CRD, RBD and LSD	4
7	Analysis of Covariance in CRD	4
8	Analysis of Covariance in RBD	4
9	Analysis of (2^2) Factorial Experiment	4
10	Analysis of (2^3) Factorial Experiment	4
11	Total and Partial Confounding	4
12	Simple Random Sampling and Sample Size Determination	4
13	Stratified, Systematic and Cluster Sampling	4
14	Ratio and Regression Methods of Estimation	4
15	Two-Stage and Multi-Stage Sampling	4

Course Outcomes:

After successful completion of this course, :

1. Students will be able to develop the ability to apply tools of analysis of CRD, RBD and LSD
2. Students will be able to develop the ability to apply tools of analysis of CRD, RBD and LSD to missing observations
3. Students will be able to develop the ability in determinations of sample size
4. Students will be able to develop the ability in determinations of samples from Simple random sampling, Stratified sampling, Cluster sampling, Systemic sampling

Paper Name: - Quality Management	Course Code:
Paper Number: DSE2-3	Credits: 02

Course Objectives:

To learn about to:

1. Meaning and dimensions of quality and its importance in real life and in manufacturing industry.
2. Different tools and techniques involved in process and product control.
3. Concept and real life application of reliability theory.

.Unit	Content	Hours
I	**Statistical Quality Control (SQC):** Meaning and purpose of SQC, quality of product, process control, product control, SPC tools: assignable causes, chance causes. Shewhart's control chart: construction, working, theoretical basis, 3σ –control limits and lack of control situation. Control charts for variables: Control chart for process average ($\bar{X}$), control chart for process variation (R), Construction and working of and R chart for known and unknown standards, revised control limits, estimate of process s. d. Control charts for attributes: Defects, defectives, fraction defective, control chart for fraction defectives (P-chart) for fixed sample size and unknown standards, construction, working of chart, revised control limits. Control chart for number of defects(C-chart): for standards are not given, construction and working of the chart, revised control limits.	10
II	**Quality Tools:** Meaning and dimensions of quality, quality philosophy, magnificent tools of quality: Histogram, Check sheet, Pareto diagram, cause and effect diagram, scatter diagram, control chart, flow chart. Deming's PDCA cycle for continuous improvements and its applications.	10
III	**Process Control:** CUSUM chart, tabular form, use of these charts for monitoring process mean. Moving average and exponentially weighted moving average charts. Introduction to six-sigma methodology, DMAIC cycle and case studies.	12
IV	**Product Control:** Sampling Inspection plans for attribute inspection: Concept of AQL, LTPD, Consumer's risk, producer's risk, AOQ, AOQL, OC, ASN and ATI. Description of Single and double sampling plans with determination of above constants.	13

Course Outcomes:

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

1. Students will be able to understand the concept of quality and dimensions of quality
2. Students will be able to find importance in real life and in manufacturing industry.
3. Students will be able to apply different tools and techniques involved in process and product control.
4. Students will be able to understand the concept and real life application of reliability theory

Recommended Book:

Introduction to quality Control–Montgomery D. C.

Reference Books:

1. Quality Control and Industrial statistics- Duncan A J
2. Statistical Quality Control- E L Grant
3. Dr. B.G. Kore and Dr. P. G. Dixit: Statistical Methods-II, 4th Edition, December, 2017, Nirali Prakashan, Pune.

Paper Name: Practical based on DSE2-3 (Quality Management)	**Course Code:**
Paper Number: DSE2-3(P)	**Credits: 01**

Course Objectives:

To learn about to:

1. To develop the ability to solve the problems of LPP, Assignment problem, Transportation problem Sequencing problem.
2. To develop the ability to solve the solve simulation problems
3. To develop the ability to detect sample defective by EWMA chart, Mean chart, P chart R chart, CUSUM chart.
4. To develop the ability to apply single and double sampling plan.

Expt. No.	Title of Practical	Hours
1	Study of basic concepts in Statistical Quality Control (SQC)	4
2	Numerical problems on control limits using 3σ limits	4
3	Construction of (\bar{X})-Chart and R-Chart	4
4	Numerical problems on (\bar{X}) and R charts with known and unknown standards	4
5	Determination of revised control limits for control charts	4
6	Construction and interpretation of P-Chart and C-Chart	4
7	Preparation and interpretation of Histogram and Check Sheet	4
8	Construction of Pareto Diagram, Cause-Effect Diagram and Scatter Diagram	4
9	Numerical problems on CUSUM, Moving Average and EWMA charts	4
10	Numerical problems on Sampling Inspection Plans and OC Curve	4

Course Outcomes:

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

1. Students will be able to develop the ability to solve the problems of LPP, Assignment problem, Transportation problem Sequencing problem.
2. Students will be able to develop the ability to solve the solve simulation problems
3. Students will be able to develop the ability to detect sample defective by EWMA chart, Mean chart, P chart R chart, CUSUM chart.
4. Students will be able to develop the ability to apply single and double sampling plan.

Paper Name: Time series analysis and reliability theory	**Course Code:**
Paper Number: DSE2-4	**Credits: 02**

Course Objectives:

To learn about to:

a) Concept behind features of time series data.

b) Tools and techniques involved to understand trend in time series analysis.

c) Impact of trend, seasonality on time series data.

Unit	Content	Hours
I	**Time series data, estimation and smoothing:** Studying a given series by plots and Histograms. Test of randomness of a series against trend and seasonality. Progressive average method, Exponential smoothing, Forecasting based on smoothing, Double exponential smoothing, Choosing parameters for smoothing and forecasting, Estimating mean square error of forecasting, Prediction intervals based on normality assumption. Ratio to trend method, Link Relative Method. Measurement of cyclic variation- Harmonic analysis.	15
II	**Detailed study of stationary process:** Definition of Stationary Time Series, Auto-Covariance, Auto-Correlation. Properties of Auto- covariance function (Statement only). Illustrative examples. MA(q) Process: Auto-covariance function, Auto-correlation function. Estimation of parameters (For MA(1) and MA(2) process only). Illustrative examples. AR(p) Process: Auto-covariance function, Auto-correlation function. Estimation of parameters (For AR(1) and AR(2) process only). Illustrative examples.	10
III	**Reliability Theory:** Binary system: Block diagram, definition of binary coherent structure and illustrations. Coherent system of component (at most three)- a) Series b) Parallel c) 2 out of 3 system. Minimal cut, minimal path representation of system. Reliability of binary system: reliability of above systems h(p),when components are independent and identically distributed with common probability p of operating. 'S' shaped ness property of h (p) without proof.	10
IV	**Ageing Properties of components:** Ageing Properties: Definitions, Hazard rate, hazard function, survival function, concept of distributions with increasing and decreasing failure rate (IFR, DFR). Relationship between	10

	survival function and hazard function, density function and hazard rate, derivations of the results a) Hazard rate of a series system of components having independent lifetimes is summation of component hazard rates. b) Lifetime of series system of independent components with independent IFR life times is IFR. Examples on exponential and Weibull distributions.	

Course Outcomes:

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

a) Students will be able understand the concept of time series data.

b) Students will be able to apply the tools and techniques involved to understand trend in time series analysis.

c) Students will be able to Impact of trend, seasonality on time series data.

d) Students will be able to understand the concept of reliability theory and its applications

Recommended Book:

Montgomery, D.C. and Johnson L.A. (1976): Forecasting and Time series Analysis, McGraw Hill.

Reference Books:

1. The Analysis of Time Series an Introduction Sixth Edition: Chris Chatfield CRC press Taylor and Francis Group, A Chapman And Hall Book
2. Farmum, N. R. and Stantorr, L.W. (1989). Quantitative Forecasting Methods, PWS-Kent Publishing Company, Boston.
3. Dr. B.G. Kore and Dr. P. G. Dixit: Statistical Methods-I, Nirali Prakashan, Pune.
4. Zacks S.: Introduction to Reliability Analysis, Probability Models
5. Barlow, R.E. and Proschan Frank: Statistical Theory of Reliability and Life Testing, Holt Rinebart and Winston Inc., New York.
6. Sinha S.K.: Reliability and Life Testing, Second Edition, Wiley Eastern Ltd. New Delhi.
7. Trivedi R.S.: Probability and Statistics with Reliability and Computer Science Application, Prentice – Hall of India Pvt. Ltd., New Delhi.

Paper Name: practical's based on Time series analysis and reliability theory	**Course Code:**
Paper Number: DSE2-4 (P)	**Credits: 01**

Course Objectives:

To learn about to:

a) Concept behind features of time series data.

b) Tools and techniques involved to understand trend in time series analysis.

c) Impact of trend, seasonality on time series data.

Expt. No.	**Title of Practical**	**Hours**
1	Plotting and graphical study of time series data	4
2	Test of randomness for trend and seasonality	4
3	Estimation using Progressive Average Method	4
4	Forecasting using Exponential and Double Exponential Smoothing	4
5	Measurement of seasonal variation using Ratio to Trend and Link Relative Methods	4
6	Numerical problems on Auto-Covariance and Auto-Correlation functions	4
7	Numerical problems on MA(1), MA(2), AR(1) and AR(2) processes	4
8	Construction of reliability block diagrams and reliability calculation of systems	4
9	Determination of Hazard Rate, Survival Function and IFR/DFR properties	4
10	Applications of Exponential and Weibull distributions in Reliability Theory	4

Course Outcomes:

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

1. Students will be able understand the concept of time series data.
2. Students will be able to apply the tools and techniques involved to understand trend in time series analysis.
3. Students will be able to Impact of trend, seasonality on time series data.
4. Students will be able to understand the concept of reliability theory and its applications

Paper Name: Hands on Training based on DSE2-3 or DSE 2-4	**Course Code:**
Paper Number: VSC4	**Credits: 02**

Course Objectives: To learn about to:

1. Apply theoretical concepts to solve the problems on statistical inference , Probability theory
2. Apply theoretical concepts to solve the problems on Time series
3. Apply theoretical concepts to solve the problems on Quality management problems
4. Apply theoretical concepts to solve the problems on design of experiment problems
5. Apply theoretical concepts to solve the problems on reliability theory

Expt. No.	Title of Practical / Hands on Training	Related Paper	Hours
1	Construction of $\bar{X}$-Chart using industrial sample data	DSE2-3 Quality Management	4
2	Construction of R-Chart for process variability	DSE2-3 Quality Management	4
3	Preparation of P-Chart for fraction defective items	DSE2-3 Quality Management	4
4	Construction of C-Chart for number of defects	DSE2-3 Quality Management	4
5	Preparation and interpretation of Histogram for quality analysis	DSE2-3 Quality Management	4
6	Construction of Pareto Diagram for defect classification	DSE2-3 Quality Management	4
7	Preparation of Cause and Effect (Fishbone) Diagram	DSE2-3 Quality Management	4
8	Numerical problems on CUSUM and EWMA Charts	DSE2-3 Quality Management	4
9	Determination of AQL, LTPD, Producer's Risk and Consumer's Risk	DSE2-3 Quality Management	4
10	Numerical problems on Single and Double Sampling Inspection Plans	DSE2-3 Quality Management	4
11	Plotting and graphical analysis of time series data	DSE2-4 Time Series Analysis and Reliability Theory	4
12	Test of randomness for trend and seasonality	DSE2-4 Time Series Analysis and Reliability Theory	4
13	Estimation using Progressive Average Method	DSE2-4 Time Series Analysis and Reliability Theory	4
14	Forecasting using Exponential Smoothing	DSE2-4 Time Series Analysis and Reliability Theory	4
15	Forecasting using Double Exponential Smoothing	DSE2-4 Time Series Analysis and Reliability Theory	4

16	Measurement of seasonal variation using Ratio to Trend Method	DSE2-4 Time Series Analysis and Reliability Theory	4
17	Numerical problems on Auto-Covariance and Auto-Correlation	DSE2-4 Time Series Analysis and Reliability Theory	4
18	Numerical problems on AR(1), AR(2), MA(1) and MA(2) processes	DSE2-4 Time Series Analysis and Reliability Theory	4
19	Reliability calculation for Series, Parallel and 2-out-of-3 systems	DSE2-4 Time Series Analysis and Reliability Theory	4
20	Numerical problems on Hazard Rate and Survival Function	DSE2-4 Time Series Analysis and Reliability Theory	4

Note : "All the above hands-on training sessions shall be conducted using R/Python programming and relevant statistical software tools."

Course outcome:

After successful competition of the course student will be able to

- Students will be able to apply theoretical concepts to solve the problems on statistical inference , Probability theory
- Students will be able to apply theoretical concepts to solve the problems on Time series
- Students will be able to apply theoretical concepts to solve the problems on Quality management problems
- Students will be able to apply theoretical concepts to solve the problems on design of experiment problems
- Students will be able to apply theoretical concepts to solve the problems on reliability theory

FP2/CEP2/OJT1: Field Projects / Internships / Apprenticeships / Community Engagement Projects / On-Job Training

Credits: 02
Marks: 20 (CA) + 30 (UA) = 50

Objectives

- To provide practical exposure to statistical applications in real-life situations.
- To develop data collection, analysis, interpretation, and reporting skills.
- To enhance employability and professional competency through field-based training.
- To apply statistical software and analytical techniques in industry, research, healthcare, business, and social sectors.

Nature of Activities

- Field Survey / Statistical Survey
- Internship in Industry / Research Institute / Hospital / NGO
- Community-based statistical project
- Apprenticeship in data analysis or quality control
- On-Job statistical training
- Mini research project
- Data collection and report preparation
- Statistical analysis using R/Python/MS-Excel

Suggested Areas

- Healthcare statistics
- Quality control
- Agricultural survey
- Educational survey
- Market research
- Financial data analysis
- Population studies
- Time series analysis
- Reliability analysis
- Industrial process analysis

Report Format

1. Title of Project/Training
2. Objectives
3. Methodology
4. Data Collection
5. Statistical Analysis
6. Interpretation of Results
7. Conclusion

8. References

Evaluation Pattern

Component	Marks
Field Work / Training Performance	10
Project Report	20
Viva-Voce / Presentation	20

Course Outcomes

- Apply statistical techniques to real-world problems.
- Collect, organize, analyze, and interpret data scientifically.
- Use statistical software tools for practical applications.
- Prepare technical reports and communicate statistical findings effectively.

Note

The project/training shall preferably be completed using R, Python, MS-Excel, or other suitable statistical software tools.