

Progressive Education Society's

Modern College of Arts, Science and Commerce,

Shivajinagar, Pune - 5

Third Year of B.Sc. (NEP 2023) Syllabus

Course under NEP 2020

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5101

Course Name: Distribution theory

Teaching Scheme: 4 Hours/Week

Credit: 04

Examination Scheme: CIA: 40 Marks

End-Sem: 60 Marks

Prerequisite Courses:

- Basic knowledge of calculus.
- Basic knowledge of probability models.

Course Objectives: The students will learn:

- Various standard probability distributions.
- Relationship between standard probability distributions.
- Applications of standard probability distributions.

Course Outcomes: At the end of the course the students are expected to:

1. Define continuous bivariate random variable.
2. Illustrate the concepts of expectations, moments, mgf. of continuous bivariate random variable.
3. Define standard continuous probability distributions.
4. Study inter-relations of continuous probability distributions
5. Study properties of continuous probability distributions
6. Understand the concept of order statistic.

Course Contents

	Title and content	Lectures
Unit I	Continuous Bivariate Distributions	10
	1.1 Continuous bivariate random vector or variable (X, Y): Joint p. d. f., joint c. d. f, properties (without proof), probabilities of events related to random variables (events in terms of regions bounded by regular curves, circles, straight lines). Marginal and conditional distributions. 1.2 Expectation of r.v.(X,Y), expectation of function of r.v. $E[g(X, Y)]$, joint moments, $Cov(X, Y)$, $Corr(X, Y)$, conditional mean, conditional variance, $E[E(X Y = y)] = E(X)$ & $E[E(Y X = x)] = E(Y)$, regression as a conditional expectation. Theorems on expectation: (i) $E(X + Y) = E(X) + E(Y)$, (ii) $E(XY) = E(X) E(Y)$, if X and Y are independent, generalization to k variables. $E(aX + bY + c)$, $Var(aX + bY + c)$ (statement only proof not expected). Independence of random variables X and Y and also its extension to k random variables. Moment generating function (MGF): $M_{X,Y}(t_1, t_2)$, properties, MGF of marginal distribution of random variables(r.v.s.), properties i) $M_{X,Y}(t_1, t_2) = M_X(t_1, 0) M_Y(0, t_2)$ if X and Y are independent r.v.s., ii) $M_{X+Y}(t) = M_{X,Y}(t, t)$ iii) $M_{X+Y} = M_X(t) M_Y(t)$ if X and Y are independent r.v.s. Probability distribution of transformation of bivariate r. v. $U = \phi_1(X, Y)$, $V = \phi_2(X, Y)$. examples on bivariate normal distribution.	

Unit II	Standard continuous probability distributions	
1	Beta distributions	10
	Beta distribution of first kind: p.d.f. $f(x) = \frac{1}{B(m, n)} x^{m-1} (1-x)^{n-1} ; 0 \leq x \leq 1, m, n > 0$ Notation : $X \sim \beta_1(m, n)$, Nature of probability curve, symmetry, mean, variance, properties, r^{th} raw moment, harmonic mean, median for $\beta_1(m, m)$. Relation with $U(0,1)$. The probability distributions of $\frac{1}{X}, X+Y, X-Y, XY, \frac{X}{Y}$ where X and Y are i.i.d $\beta_1(1, 1)$. Beta distribution of second kind: p.d.f. $f(x) = \frac{1}{B(m, n)} \frac{x^{m-1}}{(1+x)^{m+n}} ; x \geq 0, m, n \geq 0$ Notation : $X \sim \beta_2(m, n)$, Nature of probability curve, symmetry, mean, variance, properties, r^{th} raw moment, harmonic mean, median for $\beta_2(m, m)$. Interrelation between $\beta_1(m, n)$ and $\beta_2(m, n)$. Distribution of $\frac{X}{Y}, \frac{X}{X+Y}$ etc. when X and Y are independent gamma variates. Relation between distribution functions of $\beta_1(m, n)$ and binomial distribution. Real life situations and applications and model sampling using R.	
2	Cauchy Distribution	06
	p.d.f. $f(x) = \frac{\lambda}{\pi} \frac{1}{\lambda^2 + (x - \mu)^2} ; -\infty \leq x, \mu \leq \infty ; \lambda \geq 0$ Notation: $X \rightarrow C(\mu, \lambda)$, Nature of probability curve. Distribution function, quartiles, non – existence of moments, distribution of i) $1/X$ ii) X^2 iii) $aX + b$, where $X \sim C(0, 1)$. Additive property for two independent Cauchy variates (statement only). Statement of distribution of the sample mean, comment on limiting distribution of sample mean. Relationship with uniform, Student's -t and normal distributions. Applications of $C(\mu, \lambda)$	

3	Weibull Distribution	06
	p.d.f. $f(x) = (\alpha / \beta) * (x / \beta)^{\alpha-1} * \exp(-(x / \beta)^\alpha), \quad x \geq 0, \alpha, \beta > 0$ Notation : $X \sim W(\alpha, \beta)$. probability curve, location parameter, shape parameter, scale parameter. Distribution function, quartiles, mean and variance, coefficient of variation. Relationship with gamma and exponential distribution. Hazard rate, IFR and DFR property. Real life situations and applications, model sampling.	
4	Laplace (Double exponential) distribution	06
	p.d.f $f(x) = \frac{\lambda}{2} \exp(-\lambda x - \mu), \quad -\infty < x, \mu < \infty, \lambda > 0$ Notation: $X \sim L(\mu, \lambda)$. Nature of the probability curve. Distribution function, quartiles, comment on MLE of μ, λ. MGF, CGF, moments and cumulants, $\beta_1, \beta_2, \gamma_1, \gamma_2$. Laplace distribution as the distribution of the difference of two i.i.d. exponential variates with mean $(1/\lambda)$. Applications and real life situations, model sampling.	
5	Lognormal distribution	07
	p.d.f. $f(x) = \frac{1}{(x-a)\sigma\sqrt{2\pi}} \exp\left(-\frac{(\log(x-a) - \mu)^2}{2\sigma^2}\right), \quad X > a,$ $-\infty < \mu < \infty, \sigma > 0$ Notation: $X \sim LN(a, \mu, \sigma^2)$. Nature of the probability curve. Moments (r^{th} moment of $(X - a)$), first four moments, β_1 and γ_1 coefficients, quartiles, mode. Relation with $N(\mu, \sigma^2)$ distribution Distribution of $\prod X_i$, X_i's are independent lognormal variates. Applications and real life situations, model sampling.	
6	Compound and Mixture distributions	05
	Introduction to compound and mixture distributions; compound and mixture of Binomial distribution, Poisson distribution ; compound and mixture of normal distribution.	

Unit III	Order Statistics	10
	Order statistic for a random sample of size n from a continuous distribution, definition. Derivation of distribution function and density function of the i-th order statistic $X_{(i)}$, particular cases for $i = 1$ and $i = n$. Distribution of $X_{(i)}$ for random sample from uniform and exponential distribution. Derivation of joint p.d.f. of $(X_{(i)}, X_{(j)})$, probability distribution of sample range $X_{(n)} - X_{(1)}$. Distribution of sample median. $\text{Corr}(X_{(i)}, X_{(j)})$ when $X_1, X_2, \dots, X_n$ are i.i.d uniform r.v.s, distribution of $X_{(n)} - X_{(1)}$ and sample median. Comment on unbiased estimator of θ for $U(0, \theta)$ and exponential(θ) based on order statistics. Joint distribution of $X_{(1)}, X_{(2)}, \dots, X_{(n)}$	
References:		
1. Bhuyan K.C (2010): Probability Distribution Theory and Statistical Inference .		
2. Dasgupta Anirban, (2010). Fundamentals of Probability: A First Course, Springer Publication		
3. H. Cramer: Mathematical Methods of Statistics, Asia Publishing House, Mumbai.		
4. Mood, A.M. Graybill, F.Bose, D.C: Introduction to Theory (III rd Edition) Mc-Graw Hill Series.		
5. B.W. Lindgren: Statistical Theory (3 rd Edition) Collier Macmillan International Edition, Macmillan Publishing Co. Inc. New York.		
6. Sanjay Arora and Bansilal: New Mathematical Statistics (1 st Edition), Satya Prakashan 16/17698, New Market, New Delhi, 5(1989).		
7. S.C. Gupta and V. K. Kapoor: Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 88 Darya Ganj, New Delhi.		
8. V.K. Rohatgi: An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd. New Delhi.		

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5102

Course Name: Statistical Inference

Teaching Scheme: 4 Hours/Week

Credit: 4

Examination Scheme: CIA: 40 Marks

End-Sem: 60 Marks

Prerequisites:

- Knowledge of probability and probability models
- Sampling distributions

Course Objectives: The students will learn

- To study various methods of estimation of parameters and functions of parameters.
- To make comparison between the various types of estimators.
- To obtain best estimators and applications of different methods of estimations of parameters for standard probability models.
- To perform the Most Powerful and Uniformly Most Powerful tests for the parameters to be tested.
- The Need of various non-parametric tests.

Course Outcomes: At the end of the course the students are expected to:

1. To learn concept parameter, parameter space, estimator.
2. To study general problem of estimating an unknown parameter by point and interval estimation.
3. To obtain an unbiased estimator, sufficient estimator, efficient estimator for various distribution.
4. To obtain a confidence interval for a parameter.
5. Derive the Most Powerful and Uniformly Most Powerful tests for various pmfs/pdfs.
6. Distinguish between Most Powerful and Uniformly Most Powerful tests.
7. Apply parametric or non-parametric tests depending on nature of the real-life data.

Unit	Title and content	Lectures
Unit 1	Point Estimation	02
	1.1 Notion of a parameter, parameter space, sample space as a set of all possible values of $(X_1, X_2, \dots, X_n)$, general problem of estimating an unknown parameter by point and interval estimation. 1.2 Notion of a parameter, parameter space, sample space as a set of all possible values of $(X_1, X_2, \dots, X_n)$, general problem of estimating an unknown parameter by point and interval estimation. 1.3 Mean Squared Error (MSE) of an estimator.	
Unit 2	Methods of Estimation	10
	2.1 Method of moments: Derivation of moment estimators for standard distributions. 2.2 Definition of likelihood as a function of unknown parameter, for a random sample from i) discrete distribution ii) continuous distribution, distinction between likelihood function and p.d.f./p.m.f. 2.3 Method of maximum likelihood: Derivation of maximum likelihood estimator (M.L.E.) for parameters of standard distributions Use of iterative procedure to derive M.L.E. of location parameter μ of Cauchy, truncated binomial and Poisson distributions truncated at zero. Invariance property of M.L.E. 2.4 a) M.L.E. of θ in uniform distribution over i) $(0, \theta)$ ii) $(-\theta, \theta)$ iii) $(m\theta, n\theta)$ ($m < n$) b) M.L.E. of θ in $f(x; \theta) = \text{Exp} \{-(x - \theta)\}$, $x > \theta$. c) M.L.E. of location parameter in Laplace distribution. Illustrations of distributions, where M.L.E. and moment estimators are same and distinct.	
Unit 3	Criteria of Estimation	15
	3.1 Unbiasedness: Definition of an unbiased estimator, biased estimator, positive and negative bias, illustrations and examples (these should include unbiased and biased estimators for the same parameters). Proofs of the following results regarding unbiased estimators: a) Two distinct unbiased estimators of (θ) give rise to infinitely many estimators. b) If T is an unbiased estimator of θ, then $\phi(T)$ is unbiased estimator of $\phi(\theta)$ provided $\phi(\cdot)$ is a linear function. 3.2 Notion of uniformly minimum variance unbiased estimator (UMVUE), uniqueness of UMVUE whenever it exists. 3.3 Sufficiency: Concept and definition of sufficiency, statement of the Fisher-Neyman factorization theorem with proof for discrete probability distribution. Pitman – Koopman form and sufficient statistic; Exponential family of probability distributions with single	

	valued parameter and sufficient statistic. Proofs of the following properties of sufficient statistics: - If T is sufficient for θ, then $\phi(T)$ is also sufficient for θ provided ϕ is a one to one and onto function. - If T is sufficient for θ then T is also sufficient for $\phi(\theta)$. - M.L.E. is a function of sufficient statistic. 3.4 Efficiency: Definition, concept, relative efficiency of T_1 w.r.t. T_2 for (i) unbiased (ii) biased estimators. 3.5 Fisher information function: Amount of information contained in statistic $T = T(X_1, X_2, \dots, X_n)$. Statement regarding information in sample and in a sufficient statistic T. 3.6 Cramer- Rao Inequality: Statement and proof of Cramer – Rao inequality, Cramer – Rao Lower bound (CRLB), definition of minimum variance bound unbiased estimator (MVBUE) of $\phi(\theta)$. Proofs of following results: a) If MVBUE exists for θ then MVBUE exists for $\phi(\theta)$ where $\phi(\cdot)$ is a linear function. b) If T is MVBUE for θ then T is sufficient for θ. Comparison of variance with CRLB, Efficiency of unbiased estimator T w.r.t. CRLB.	
Unit 4	Interval Estimation	03
	4.1 Notion of interval estimation, definition of confidence interval (C.I), length of C.I., Confidence bounds, confidence coefficient. Definition of pivotal quantity and its use in obtaining confidence intervals. 4.2 Interval estimation for the following cases: i) Mean (μ) of normal distribution (σ^2 known and σ^2 unknown). ii) Variance (σ^2) of normal distribution (μ known and μ unknown).	
Unit 5	Parametric Tests	04
	5.1 Statistical hypothesis, problem of testing of hypotheses. Definition and illustrations of (i) simple hypothesis, (ii) composite hypothesis, (iii) test of hypothesis, (iv) critical region, (v) type I and type II errors. Probabilities of type I error and type II error. Problem of controlling the probabilities of errors of two kinds. 5.2 Definition and illustrations of (i) level of significance, (ii) observed level of significance (p-value), (iii) size of a test, (iv) power of a test.	
Unit 6	Most Powerful and Uniformly most powerful tests	11
	6.1 Non-randomised test functions. Definition of most powerful (M.P.) level α test of simple null hypothesis against simple alternative. Statement of Neyman - Pearson (N-P) lemma for constructing the most powerful level α test of simple null hypothesis against simple alternative hypothesis. Illustrations. 6.2 Power function of a test, power curve, definition of uniformly most powerful (UMP) level α test for one sided alternative. Illustrations.	

Unit 7	Non-parametric Tests	15
	7.1 Concept of non- parametric tests. Distinction between parametric and nonparametric Tests. Concept of distribution free statistic. One tailed and two tailed test procedure of i) Sign test, ii) Wilcoxon signed rank test iii) Mann Whitney U test, iv) Run test, one sample and two samples problems. 7.2 Empirical distribution function $S_n(x)$. Properties of $S_n(x)$ as estimator of $F(\cdot)$. Kolmogorov – Smirnov test for completely specified univariate distribution (one Sample problem only) for two sided alternative hypotheses. Complexity with chi-square test.	

References:

1. Agarwal, B.L. (2003). Programmed Statistics, second edition, New Age International Publications, Delhi
2. Bhuyan K.C(2010). Probability Distribution Theory and Statistical Inference , New Central Book Agency.
3. Casella, G. and Berger, R. L. (2002). Statistical Inference. Duxbury Advanced Series, Second Edition.
4. Daniel, W.W. (2000) Applied Nonparametric Statistics, Duxbury Press Boston.
5. Dudewitz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, John Wiley and Sons, Inc.
6. Gibbons J.D. (1971). Non parametric Statistical Inference, McGraw Hill Book Company, New York.
7. Hoel, P.G.,Port, S. and Stone, C. (1971). Introduction to Statistical Theory, Houghton Mifflin Company (International)
8. Hogg, R.V. and Craig, R.G. (1989). Introduction to Mathematical Statistics (fourth edition,.Collier Macmillan International Edition, Macmillan Publishing Co. Inc., New York.
9. Kale, B.K. and Muralidharan, K. (2015). Parametric Inference: An Introduction. Narosa, New Delhi
10. Kendall, M. and Stuart, A. (1943) The advanced Theory of Statistics, Vol 1, Charles and Company Ltd., London.
11. Kunte, S ., Purohit, S.G. and Wanjale, S.K. : Lecture Notes On Nonparametric Tests
12. Larry Wasserman (2006). All of Nonparametric Statistics, Springer-Verlag New York Publication John Wiley and Sons, Inc.
13. Larry Wasserman (2013). All of Statistics: A Concise Course in Statistical Inference, Springer Texts in Statistics.
14. Mood, A.M., Graybill, F. and Bose, D. C .(1974). Introduction to the theory of Statistics (third edition) International Student Edition, McGraw Hill.
15. Rohatgi, V.K. A. K. Md. Ehsanes Saleh (1976). An Introduction to Probability and Statistics Second Edition, A Wiley- Interscience

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5103

Course Name: Lab course on 23ScStaU5101 & 23ScStaU5102

Teaching Scheme: 4 Hours/Week

Credit: 2

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisites:

- Knowledge of descriptive statistics.
- Knowledge of probability and probability models.

Course Objectives: The students will learn

- To simulate random sampling from some continuous probability distributions.
- To construct confidence interval from quartiles and correlation coefficient.
- Methodology to compute M.L.E., Moment estimator of parameter under study
- To perform the Most Powerful and Uniformly Most Powerful tests for the parameters to be tested.
- The need of various non-parametric tests.

Course Outcomes: At the end of the course the students are expected to:

1. Simulate random sample from Cauchy, beta first and second distribution Weibull, Laplace distribution. lognormal and Pareto distribution
2. Construct of confidence interval for population median, quartile, correlation coefficient.
3. Calculate M.L.E., Moment estimator of truncated Binomial and truncated Poisson (truncated at zero)
4. Derive the Most Powerful and Uniformly Most Powerful tests for various pmfs/pdfs.
5. Distinguish between Most Powerful and Uniformly Most Powerful tests.
6. Apply parametric or non-parametric tests depending on nature of the real-life data.

Sr. No.	Title of experiment	Number of Practicals
1	Simulation from Cauchy, beta first and second kind distribution	1
2	Simulation from Weibull, Laplace distribution.	1
3	Simulation from lognormal and Pareto distribution	1
4	Fitting of lognormal distribution.	1
5	Construction of confidence interval for population median, quartile.	1
6	Construction of confidence interval for correlation coefficient using pivotal quantity.	1
7	M.L.E. of truncated Binomial and truncated Poisson (truncated at zero)	1
8	Moment estimator of truncated Binomial and truncated Poisson (truncated at zero)	1
9	Testing of hypotheses (Probability of type I error and type II error, power of test)	1
10	Construction of Most Powerful test and plotting of power function.	1
11	Construction of Uniformly Most Powerful test (UMP) test and plotting of power function.	1
12	Non - Parametric Test (Sign test, Wilcoxon's Signed Rank test, Mann-Whitney U test).	1
13	Non - Parametric Test (Run Test, Kolmogorov- Smirnov Test).	1
14-15	Experiential learning	2

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5201

Course Name: Regression Analysis (T)

Teaching Scheme: 2 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisites: Probability Models, Sampling distributions and inference

Course Objectives: The students will understand

- Fitting of simple linear regression model
- Fitting of multiple linear regression model
- Logistic regression model
- Testing significance of regression
- Regression diagnostics and residual analysis
- Model building

Course Outcomes: After completion of the course students will be able to fit an appropriate regression model to real life data sets.

1. Analyse bivariate data using scatter plots and correlation measures to determine relationships between variables.
2. Apply the least squares method to estimate regression parameters and evaluate model adequacy using hypothesis tests, ANOVA, and residual analysis.
3. Construct multiple linear regression models by estimating parameters using the least squares method and solving normal equations.
4. Evaluate model adequacy through statistical tests, detection of multicollinearity, and selection of optimal regression models.
5. Develop and interpret univariate logistic regression models, including parameter estimation and hypothesis testing.
6. Assess model fit using deviance, likelihood ratio tests, and other statistical measures

Course Contents:

Unit	Title and Content	No. of lectures
Unit 1	Simple Linear Regression Model	10
	1.1 Bivariate data, Scatter Diagram and Correlation 1.2 Fitting of simple linear regression model: $Y = \beta_0 + \beta_1 X + \varepsilon$ where ε is a continuous random variable (error component) with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma^2$. Estimation of β_0 and β_1 by the method of least squares. 1.3 Properties of estimators of β_0 and β_1 . 1.4 Estimation of σ^2 . 1.5 Interval estimation in simple linear regression model. 1.6 Evaluating the regression model (Tests of hypothesis of β_1 , Analysis of variance, Coefficient of determination, adjusted coefficient of determination.) 1.7 Residual analysis: Standardized residuals, Studentized residuals, residual plots, PRESS residual. 1.8 Corrective measures: dealing with non-constant variance and non-linearity. 1.9 Outliers: Detection and treatment.	
Unit 2	Multiple linear regression model	12
	2.1 Introduction to linear algebra. 2.2 Multiple linear regression model: $Y = \beta_0 + \beta_1 X_1 + \dots + \beta_p X_p + \varepsilon$ Estimation of regression parameters $\beta_0, \beta_1, \dots, \beta_p$ by the method of least squares, obtaining normal equations, solutions of normal equations. 2.3 Estimation of σ^2 . 2.4 Interval estimation for regression coefficients. 2.5 Assessing adequacy of model: Tests for significance of regression, tests for individual regression coefficients, coefficient of determination 2.6 Multicollinearity: detection and treatment. 2.7 Model building: Criteria for evaluating subset regression models, computational techniques for variable selection.	
Unit 3	Logistic regression model	8
	3.1 Introduction to logistic regression 3.2 Univariate logistic regression model: Defining and fitting the model, interpretation of parameters and testing of hypotheses of model parameters, deviance, LR test	

References:

1. Chatterjee S. and Hadi A.S. (2012): Regression Analysis by Example, 5th Edition, Wiley.
2. Draper, N. R. and Smith, H. (1998). Applied Regression Analysis Third Edition, John Wiley.
3. Hosmer, D. W. and Lemeshow, S. (1989). Applied Logistic Regression, Wiley.
4. Kleinbaum G. and Klein M. (2011): Logistic Regression, IIIrd Edition A Self learning text, Springer
5. Montgomery, D. C., Peck, E. A. and Vining, G. G. (2003): Introduction to Linear Regression Analysis, Wiley.
6. Neter, J., W., Kutner, M. H., Nachtsheim, C.J. and Wasserman, W. (1996): Applied Linear Statistical Models, fourth edition, Irwin USA.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5201

Course Name: Regression Analysis (P)

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA: 20

End-Sem: 30

Sr. No.	Title of Experiment/ Practical
1	Correlation analysis and scatter plot interpretation.
2	Basics of linear algebra for regression - I
3	Basics of linear algebra for regression - II
4	Fitting and interpretation of simple linear regression model.
5	Residual analysis and diagnostics in simple linear regression.
6	Fitting of multiple linear regression model.
7	Residual analysis and diagnostics in multiple linear regression.
8	Model building using forward selection method.
9	Model building using backward elimination method.
10	Fitting and Interpretation of simple logistic regression model.
11	Odds ratio and its interpretation in logistic regression.
12	Fitting and interpretation of multiple logistic regression model.
13-15	Experiential learning.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5202

Course Name: Stochastic Processes (T)

Teaching Scheme: 2 Hours/Week

Credit: 2

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisites: Matrix theory and Probability theory

Course Objectives: The students will be able to learn

- Concept of stochastic process
- Classification of stochastic process and their states
- Applications of stochastic process.

Course Outcomes: At the end of the course the students will be able to:

1. Identify and apply the appropriate stochastic models to analyze real life data .
2. Study concept of Markov chain and calculate probabilities for various events.
3. Study stochastic processes.
4. Differentiate among types of stochastic processes.
5. Study stationary distribution of stochastic processes.
6. Estimate the parameters in stochastic processes.

Course Content:

Unit	Title and content	Lectures
Unit 1	Introduction to Stochastic Process	15
	1.1 Definition of a Stochastic process, state space, parameter space, types of stochastic processes	
	1.2 Markov chains (MC) $\{X_n, n \geq 0\}$, finite MC, time homogeneous M.C. one step transition probabilities, and transition probability matrix (t.p.m.), stochastic matrix.	
	1.3 n-step transition probability matrix, Chapman Kolmogorov equation,	
	1.4 Initial distribution, joint distribution function of	

	$\{X_0, X_1, \dots, X_n\}$, 1.5 Partial sum of independent and identically distributed random variables as Markov chain 1.6 Illustrations such as random walk, Gambler's ruin problem, Probability of ultimate ruin, expected gain. Ehrenfest chain. (Without proof).	
Unit 2	Classification of States	07
	2.1 First return probability, probability of ever return. Classification of states, as persistent and transient states. Mean recurrence time being persistent as class property. 2.2 Classification of states: Communicating states. 2.3 Decomposition of state space, closed set of states, irreducible set of states, irreducible MC. 2.4 Periodicity of M.C, Periodicity is class property, aperiodic M.C., ergodic M. C.	
Unit 3	Stationary Distribution and Poisson Process.	08
	3.1 Stationary distribution. Examples of unique, multiple and no solution. Relation between mean recurrence time and stationery probability. Case when initial distribution coincides with stationary distribution. 3.2 Stationary distribution for an irreducible ergodic finite. Long run behavior of a M.C. 3.3 Poisson process: Postulates and properties of Poisson process. 3.4 Probability distribution of $N(t)$, the number of occurrences of the event in $(0, t]$ (Statement only).	

References:

1. Adke, S.R., Manjunath, S.M. (1984). An introduction to finite Markov processes, Wiley Eastern.30
2. Bhat, B.R. (2000). Stochastic models: Analysis and applications, New Age International.
3. Hoel, P. G., Port, S.C. and Stone, C.J. (1972): Introduction to Stochastic processes, Wiley Eastern.
4. Medhi J. (1982). Stochastic processes, Wiley Eastern
5. Ross, S. (2000). Introduction to probability models, 7th edition, Academic Press
6. Ross, S. (1996) Stochastic processes, John Wiley.
7. Sivprasad Madhira, S.R.Deshmukh (2024): Introduction to Stochastic processes using R :Springer
8. Srinivasan, S.K. and Mehta, K.M. (1981). Stochastic Processes, Tata Mc-Graw Hill.
9. Taylor, H N and Karlin, S. (1984). An introduction to stochastic modelling Academic Press.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5202

Course Name: Stochastic Processes (P)

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA:20 Marks

End-Sem: 30 Marks

Prerequisites: Matrix theory and Probability theory

Course Objectives: The students will be able to learn

1. Concept of stochastic process
2. Classification of stochastic process and their states
3. Applications of stochastic process.
4. Identify and apply the appropriate stochastic models to analyze real life data .

Course Contents

Sr. No.	Title of Experiment/ Practical
1	Construction of transition probability matrix (t.p.m).
2	Realization of Markov Chain
3	Verification of Chapman Kolmogorov equations. Finding n step transition probability matrices
4	Finding $P(X_n X_{n-1})$ and $P(X_n X_1, X_2, \dots, X_{n-1})$ and marginal distribution of X_n .
5	Examples on random walk, and Ehrenfest chain.
6	Gambler's ruin problem: probability of ultimate ruin and expected gain
7	Classification of states-I. Finding mean recurrence time. Finding closed sets of MC.
8	Classification of states -II .(Recurrent , transient)
9	Periodicity and ergodicity of a Markov chain.
11	Stationary distribution of a given Markov chain.
12	Realization of Poisson process (Simulation)
13	Several examples on Poisson Process.
14-15	Experiential learning

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023) (Minor)
Course under NEP 2020

Course Code: 23ScStaU5301

Course Name: Applied Statistics I (T)

Teaching Scheme: 2 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Pre-requisite Courses: Basic probability and probability distributions.

Course Objectives:

- To study concept of correlation and regression analysis.
- To learn multiple and partial correlation.
- To learn application of various regression model.
- To learn various sampling technique.
- Identify appropriate sampling design for sampling survey.
- Fit appropriate queuing model.

Course Outcomes: On completion of the course, student will be able to—

1. To study concept of correlation and regression analysis.
2. To learn fitting of linear regression model.
3. To learn concepts of sampling technique and census.
4. Identify appropriate sampling design for the sampling survey.
5. To study queuing model for real life situation.
6. To study vital event and measure vital statistics.

Course Contents :

Unit 1	Population and Sample	5
	1.1 Notion of a statistical population, concept of population and sample from a population with illustrations, concept of census, advantage and disadvantage of census. advantage and disadvantage of sampling 1.2 Description of simple random sampling with and without replacement	

	(SRSWR and SRSWOR), Stratified random sampling, systematic sampling, cluster sampling, two stage sampling.	
Unit 2	Correlation and Regression analysis	7
	2.1 Bivariate data, Scatter diagram and interpretation. 2.2 Concept of correlation between two variables, positive correlation, negative correlation, no correlation. 2.3 Covariance between two variables, Karl Person's coefficient of correlation(r), limits of $r(-1 \leq r \leq 1)$, interpretation. coefficient of determination 2.4 Regression: Introduction, real life situations for regression and correlation simple linear regression. 2.6 Fitting of regression line using least square method. 2.7 Examples and problems.	
Unit 3	Vital Statistics	10
	3.1 Introduction, Methods of collecting vital Statistics, Mortality rates: CDR, ASDR, STDR (direct method), advantages and disadvantages. 3.2 Fertility rates: CBR, ASFR, TFR, GFR Population Growth rate: GRR and NRR, advantages and disadvantages. example and problems.	
Unit 4	Queuing Theory	8
	4.1 Introduction, calling population, queue discipline, inter arrival rate, service rate, traffic intensity, Channel 4.2 single channel Poisson arrival with exponential service rate, average waiting time in i) queue and ii) system, average length of i) queue and ii) system. 4.3 Examples and problems.	

References:

1. Dixit P.G, Prayag V.R., Descriptive Statistics, Nirali Prakashan., Pune
2. Dixit P.G. and P .S. Kapre Continuous probability distribution-II And demography.
3. Das (2009). Statistical Methods, Tata Mcgraw Hill Publishing.
4. Goon, A. M., Gupta, M. K. and Dasgupta, B. (2016). Fundamentals of Statistics, Vol. 1, 6th Revised Edition, The World Press Pvt. Ltd., Calcutta.
5. Gore. Anil, Pranjapesharayu, Kulkarni Madhav. Statistics for everyone. SIPFAcadamy publisher, Nashik
6. Gupta S.C. (2018). Fundamentals of Statistics: Himalaya Publishing House
7. Gupta S.P. (2017) . Statistical Methods, Sultan Chand & Sons publication, Delhi.
8. Kapoor V.K., Operation Research for Managerial Decision-making, publish by Sultan Chand and Sons, New Delhi
9. Kapoor V.K. Problems and solutions in Operation Research , publish by Sultan Chand and Sons, New Delhi
10. Mukhopadhyay P. (2015). Applied Statistics , Publisher: Books & Allied (P) Ltd.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5301

Course Name: Applied Statistics I (P)

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisite Courses: Basic Probability and probability distribution

Course Objectives:

- To study different type of vital events and interpret the result.
- To learn correlation and regression model.
- To Study queuing model.
- To Identify appropriate sampling design for sampling survey.

Course Contents

Sr. No.	Title of Experiment/ Practical
1	Use of random number tables to draw SRSWOR, SRSWR.
2	Use of random number tables to draw stratified sample and systematic sample.
3	Exploratory data analysis I
4	Exploratory data analysis II
5	Scatter diagram and computation of correlation coefficient (ungrouped data)
6	Fitting of line of regression for bivariate data-I
7	Fitting of line of regression for bivariate data -II
8	Computation of birth rates and fertility rates -I
9	Computation of birth rates and fertility rates -II
10	Computation of death rates and mortality rates
11	Computation of population growth rates
12	Application of queuing model.
13-15	Experiential learning (equivalent to 3 practical).

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU5501

Course Name: Lab course Statistical Analysis using Python Programming.

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisite Courses: Descriptive Statistics, discrete and continuous probability distributions, Parametric and Non -Parametric tests.

Course Objectives: To use Python as a tool for statistical computing for:

- Importing data sets using Python and importing several libraries.
- Graphical Representation of data.
- Calculation of measures of central tendency and measures of dispersion.
- Calculation of probabilities and drawing a random sample from several discrete and continuous distribution.
- Performing parametric and non-parametric tests.

Course Outcomes: On completion of the course, student will be able to perform statistical computations using Python.

Course Contents:

All practical are to be performed using Python programming.

Sr. No.	Title of Experiment/ Practical
1	Introduction to Python- I.
2	Introduction to Python- II
3	Introduction to Python- III.
4	Graphical Representation of data by importing libraries :Bar Chart, Histogram, Boxplot, pie charts ,scatter plot).
5	Use of control flow statements (if else, for and while).
6	Computation of Descriptive Statistics for ungrouped data (Measures of central tendency and measures of dispersion).
7	Computation of Descriptive Statistics for grouped data. (Measures of central tendency and measures of dispersion).
8	Measures of skewness and kurtosis (ungrouped and grouped data).

9	Computation of correlation coefficient and fitting of regression line.
10	Calculation of probabilities for standard discrete probability distributions and drawing a random sample from distributions.
11	Calculation of probabilities for standard continuous probability distributions and drawing a random sample.
12	Testing of Hypothesis I (Parametric tests)
13	Testing of Hypothesis II (Non-Parametric tests)
14	One way ANOVA.
15	Two-way ANOVA.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU6101

Course Name: Sampling Theory and Statistical Quality Control

Teaching Scheme: 4 Hours/Week

Credit: 4

Examination Scheme: CIA: 40 Marks

End-Sem: 60 Marks

Prerequisites:

- Knowledge of descriptive statistics.
- Knowledge of probability and probability models.

Course Objectives: The students will learn

- the basic knowledge of complete enumeration and sample, sampling frame, sampling distribution, sampling and non-sampling errors, principal steps in sample surveys, limitations of sampling etc.
- various statistical sampling schemes such as simple, stratified and systematic sampling.
- to conduct the sample surveys and selecting an appropriate sampling techniques.
- how to compare the various sampling techniques.

Course Outcomes: At the end of the course the students are able to:

1. Design and execute the simple random sampling with replacement and without replacement and comparison between them.
2. Understand stratified random sampling, different allocation problem of sample size in stratified random sampling and accordingly design and execute sampling.
3. Apply systematic random sampling for collecting the sample data.
4. Determine adequate sample size for various sampling procedures.
5. Use appropriate sampling design to collect data.
6. Compute estimates of parameters and variability in estimates of parameter under study according to the sample design.
7. Compare SRSWOR, SRSWR, stratified random sampling and systematic random sampling.
8. Design an appropriate control chart for given process.
9. Draw conclusions regarding state of control of process and obtain control limits for future use.
10. Apply the single and double sampling plan in the given situation.

Course Content:

Unit	Title and content	Lectures
Unit 1	Sampling	09
	1.1 Different sampling schemes, Concept of distinguishable elementary units, sampling units, sampling frame, random sample, Requisites of a good sample, Simple random sampling (Probability sampling) from finite population of size (N), i) with replacement (SRSWR) ii) without replacement (SRSWOR), 1.2 Definitions of population mean, population variance and population total as parameters, inclusion probabilities of a unit in SRS. 1.3 Sample mean ($\bar{y}$) as an estimator of population mean ($\bar{Y}$), derivation of expectation and standard error of $\bar{y}$, $N\bar{y}$ as an estimator of population total, derivation of expectation and standard error of $N\bar{y}$, Estimator of above standard errors, both in case of SRSWR and SRSWOR, confidence interval for population mean, population total, standard error. 1.4 Sampling for proportion as an application of a simple random sampling with X_i as zero or one. Sample proportion (p) as An estimator of population proportion (P) of units possessing a certain attribute, derivation of expectation and standard error of (p), Np as an estimator of total number of units in the population possessing a certain attribute, derivation of expectation and standard error of Np. Estimator of above standard error both in case of SRSWR and SRSWOR.	
Unit 2	Determination of Sample Size	04
	2.1 Determination of the sample size for estimating population mean, population total and population proportion for the given: i) Margin of error and confidence coefficient. ii) Coefficient of variation of the estimator and confidence coefficient.	
Unit 3	Stratified Random Sampling	12
	3.1 Stratification, basis of stratification, real life situation where stratification can be used. 3.2 Stratified random sampling as a sample drawn from individual strata using SRSWOR in each stratum. 3.3 $\bar{y}_{st} = \frac{\sum N_i \bar{y}_i}{N}$ as an estimator of population mean ($\bar{Y}$), derivation of expectation and standard error of $\bar{y}_{st}$, $N\bar{y}_{st}$ as an estimator of population total, derivation of expectation and standard error of $N\bar{y}_{st}$, Estimator of above standard errors. 3.4 Problem of allocation, Proportional allocation, Neyman's allocation, derivation of the expressions for the standard errors of the above estimators when these allocations are used. 3.5 Cost and variance analysis in stratified random sampling,	

	minimization of variance for fixed cost, minimization of cost for fixed variance, optimum allocation, Neyman's allocation as a particular case of optimum allocation in cost and variance analysis.	
Unit 4	Systematic Sampling (Population size divisible by sample size)	05
	4.1 Real life situations where systematic sampling is appropriate. Techniques of drawing a sample using systematic sampling. 4.2 Estimation of the population mean and population total, standard error of these estimators. Comparison of systematic sampling with SRSWOR.	
Unit 5	Statistical Quality Control: Introduction	04
	5.1 Meaning of the terms quality, six sigma, TQM and purpose of Statistical Quality Control (SPC), on line process control methods (control charts) and offline process control methods (Sampling plans). 5.2 Introduction to seven Process Control (PC) Tools of SPC (i) Check Sheet, (ii) Cause and effect diagram (iii) Pareto Diagram, (iv) Histogram, (v) Control chart, (vi) Scatter Diagram, (vii) Design of Experiments (DOE).	
Unit 6	Control charts	18
	6.1 Chance causes and assignable causes of variation, statistical basis of control charts, exact probability limits, k-sigma limits, justification for the use of 3-sigma limits for normal distribution and using Chebychev's inequality for non-normal distributions. Criteria for detecting lack of control situations: (i) At least one point outside the control limits (ii) A run of seven or more points above or below central line. (iii) Presence of a non-random pattern eg. cycle or linear trends etc. Control chart technique as hypotheses testing problem. Construction of control charts for (i) standards given, (ii) standards not given. 6.2 Control charts for variables (I) R chart and $\bar{X}$ chart construction of R chart when the process standard deviation is specified: control limits, drawing of control chart, plotting of sample ranges, determination of state of control process, corrective action if the process is out of statistical control. Construction of $\bar{X}$ chart when the process average is specified: control limits, drawing of control chart, plotting of sample means, determination of state of control of process, corrective action if the process is out of statistical control. (II) Construction of R chart when the process standard deviation (σ) is not given: control limits, drawing of control chart, plotting sample range values, revision of control limits if necessary, estimate of σ for future use. Construction of $\bar{X}$ chart when the process average μ is not given: drawing of control chart, plotting sample means, revision of control limits of $\bar{X}$ chart, if necessary. Probability of catching a shift.	

	Estimate of μ and σ for further use. Determination of state of control of the process. Identification of real life situations where this technique can be used. Limitations of $\bar{X}$, R charts. Note: To find revised control limits of any control chart delete the sample points above UCL and points below LCL (assuming a search for assignable causes at those points), in case of R and $\bar{X}$ charts, first of all, revisions of control limits of R is to be completed and then by using the observations for which R chart shows the process is under control, the control limits for $\bar{X}$ chart should be determined. Revision of control limits of $\bar{X}$ chart be continued without revising the value of R or σ. 6.3 Control charts for Attributes 6.3.1: p - chart (a) Construction and working of p-chart when subgroup sizes are same and value of the process fraction defective P is specified: control limits, drawing of control chart, plotting of sample fraction defectives. Determination of state of control of the process. (b) p-chart when subgroups sizes are different and value of the process fraction defective P is not specified with separate control limits, drawing of control chart, plotting sample fraction defectives, determination of state of control of the process. Interpretation of high and low spots. Identification of real life situations. Probability of catching a shift. 6.3.2: C chart (a) Construction of c-chart when standard is given; control limits justification of 3 sigma limits, drawing of control chart, plotting number of defects per unit. (b) Construction of c chart when standard is not given; control limits, explanation for the use of 3 sigma limits, drawing of control chart. Plotting number of defects per unit. Determination of state of control, Identification of real life situations.	
Unit 7		02
	7.1 Specification limits, natural tolerance limits and their comparisons, decisions based on these comparisons, estimate of percent defectives. 7.2 Capability ratio and capability indices (C_p), capability performance indices C_{pk} with respect to machine and process, interpretation, relationship between (i) C_p and C_{pk} (ii) defective parts per million and C_p.	
Unit 8	Acceptance Sampling Plan for Attributes	08
	8.1 Introduction: Concept of sampling inspection plan with rectification, Comparison between 100% inspection and sampling inspection. Procedures of acceptance sampling with rectification, Single sampling plan and double sampling plan. Probabilities of acceptance and rejection 8.2 Explanation of the terms: Producer's risk and Consumer's risk, Operating characteristic (OC) curve, Acceptable Quality Level (AQL), Lot Tolerance Fraction Defective (LTFD) and Lot Tolerance Percent Defective (LTPD), Average Outgoing Quality (AOQ) and Average	

	Outgoing Quality Limit (AOQL), AOQ curve, Average Sample Number (ASN), Average Total Inspection (ATI) 8.3 Single Sampling Plan: Computation of probability of acceptance using Poisson approximation, Derivation of AOQ and ATI. Graphical determination of AOQL, Determination of a single sampling plan by: a) lot quality approach b) average quality approach.	
--	---	--

References (Sampling Theory)

1. Cochran, W.G.(2007):Sampling Techniques , Third Edition, Wiley India Pvt. Ltd., New Delhi.
2. Gupta S.C., Kapoor V.K. (2014): Fundamentals of Applied Statistics, Sultan Chand & Sons.
3. Goon A.M., Gupta M.K. and Dasgupta B. (2001): Fundamentals of Statistics (Vol.2), World Press.
4. Murthy, M. N. (1977): Sampling Theory and Methods, Statistical Publishing Society, Kolkata.
5. Singh, D. and Chaudhary, F. S. (1986): Theory and Analysis of Sample Survey Designs, Wiley Eastern Ltd., New Delhi.
6. Sukhatme, P.V., Sukhatme, B. V.(1984): Sampling theory of Surveys with Applications, Indian Society of Agricultural Statistics, New Delhi.
7. Sampath S. (2005): Sampling Theory and Methods, Second edition, Narosa, New Delhi.
8. Mukhopadhyay P (2008): Theory and methods of survey sampling. Prentice-Hall of India, New Delhi.
9. Chagbao Wu and Mary E. Thompson(2020) :Sampling Theory and Practice, Springer Nature Switzerland.
10. Raghunath Arnab (2017): Survey Sampling Theory and Applications, Academic Press, Elsevier.

References (Statistical Quality Control):

11. Besterfield, D.H. and Michna, C.B. et al. (2009). Total Quality Management, 3rd edition, Pearson Education, Delhi.34
12. Dodge, H.F. and Roming, H.G. Sampling Inspection tables, John Wiley and Sons, Inc. Newyork
13. Duncan A.J. (1974). Quality Control and Industrial Statistics, fourth edition D.B. Taraporewala Sons and Co. Pvt. Ltd. Mumbai.
14. Grant, E. L. and Leavenworth (1980). Statistical Quality Control, fifth edition, Mc-Graw Hill, New Delhi.
15. Johnson, N.L. and Kotz, S. (1993). Capability Studies, Chapman and Hall Publishers.
16. Kamji and Asher (1996). 100 Methods of TQM, Sage Publishers, Delhi
17. Montgomery, D. C. (1983). Statistical Quality Control, John Wile and Sons, Inc., New York.
18. Parimal Mukhopadhyay (1999). Applied Statistics, Books & Allied Ltd

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU6102

Course Name: Data Mining and Survival Analysis

Teaching Scheme: 4 Hours/Week

Credit: 4

Examination Scheme: CIA: 40 Marks

End-Sem: 60 Marks

Prerequisites: Knowledge of probability and probability distributions

Objectives: The students shall get concepts of

- To study classification algorithm and regression algorithm in real life situation.
- To learn supervised and unsupervised algorithm for the data.
- To Study the clustering, association analysis and able to do outlier detection.
- To apply all the algorithm in real life situation
- To analysis and validation of algorithms that enable computers (machines) to learn from data.
- Structural properties of coherent system.
- Reliability of coherent system.

Course Outcomes: At the end of the course the students will be able to learn:

1. To study data cleaning process in datamining.
2. To apply various supervise learning algorithms for data analysis, particularly when data is large.
3. To apply various unsupervised learning algorithms for data analysis, particularly when data is large.
4. Apply various ML algorithms for model free Statistical Inference, which can be studied by any one from any discipline.
5. Coherent and Non-coherent systems.
6. Structural properties of a coherent system.
7. Compute reliability of a coherent system.
8. Compute importance of components of a system and to do pivotal decomposition of a complex system.

Course Content:

Unit	Title and content	Lectures
Unit 1	Introduction to Data Mining	05
	1.1 Data preparation for knowledge discovery : Data understanding and data cleaning tools, Data transformation, Data Discretization, Data Visualization. 1.2 Data Mining Process: CRISP and SEEMA, Supervised and unsupervised learning techniques.	
Unit 2	Supervised Learning	15
	2.1 Supervised learning 2.2 Learning with Classification - Decision Tree, Support Vector Machine (two-dimensional data), Naive Bayes, K-Nearest Neighbors, Logistic regression. 2.3 Evaluating model performance - False positives, False negatives Confusion matrix, Accuracy, Precision, Recall, Cross Validation and Comparison 2.4 Regression Metrics: R- Square, Adjusted R Square 2.5 Classification and Evaluation Matrix 2.6 Artificial Neural network: Concept of Deep learning, Artificial Neural network - Neurons, Activation function, Perceptron learning algorithm, training of perceptron	
Unit 3	Unsupervised Learning	06
	3.1 Un-supervised learning 3.2 Clustering algorithms - Hierarchical clustering, K-means clustering, 3.3 Rule based learning - Association rule mining, Apriori, Support and Confidence parameters and comparison.	
Unit 4	Model Evaluation, Selection and Classification Accuracy	04
	4.1 Model evaluation and selection: Metrics for evaluating classifier performance. 4.2 Concept of training data, testing data and validation of model, Cross-Validation.	

Unit 5	Survival Analysis : Introduction	22
	5.1 Definitions: Hazard rates, hazard function, survival function, Concept of distributions with increasing and decreasing failure rate (IFR/DFR), Average Increasing (Decreasing) Failure Rate (IFRA/ DFRA), 5.2 Relationship between: i) Survival function and hazard function ii) Density function and hazard rate. 5.3 No ageing, proof of the properties of no ageing: i) Cauchy functional equation ii) Constant failure rate iii) Constant means residual life iv) Exponential life distribution v) Exponential Equilibrium distribution vi) Identity function as the TTT transforms 5.5 Positive and negative ageing: IFR, DFR IFRA, DFRA, NBU, NWU, NBUE, NWUE, DMRL, IMRL, HNBUE, HNWUE, bathtub failure rate. 5.6 Proof of the Implications: $IFR \Rightarrow IFRA$, $IFR \Rightarrow DMRL$, $IFRA \Rightarrow NBU$, $NBU \Rightarrow NBUE$, $DMRL \Rightarrow NBUE$, $DFR \Rightarrow DFRA$, $DFR \Rightarrow IMRL$, $DFRA \Rightarrow NWU$, $NWU \Rightarrow NWUE$.	
Unit 6	Censoring and Nonparametric estimation of survival function	08
	6.1 Concept of censoring, order censoring, time censoring, right random censoring, left random censoring, undersigned censoring. 6.2 Nonparametric estimation of survival function, confidence band on survival function, actuarial estimator of survival function and its variance using Greenwood's formula, Kaplan Meier estimator of survival function and its variance in the presence of censored observations.	

References (Data Mining):

1. Chattamvelli, R. (2015). Data mining methods. Alpha Science International
2. Mitchell T.M. (1997): Machine Learning, McGraw-Hill.
3. Hastie T, Tibshirani R, Friedmant J, (2009): The elements of statistical Learning, Springer.
4. Han, J. and Kamber, M. and Pei, J. (2012): Data Mining: Concepts and Techniques. MorganGaufmann.3rd Edition.
5. Vapnik V.N. The nature of Statistical learning theory, Springer

References(Survival Analysis)

6. Bain Lee, Engelhardt Max (2017). Statistical Analysis of Reliability and Life-Testing Models: Theory and Methods, Second ed, Routledge publication.
7. Barlow, R. E. and Proschan F. (1975). Statistical theory of Reliability and Life testing: Probability Models Holt, Rinehart and Winston Inc.
8. Barlow, R. E. and Proschan F. (1996). Mathematical Theory of Reliability. John Wiley.
9. Cox, D.R. and Oakes, D. (1984).Analysis of Survival Data,Chapman and Hall.
- 10.Deshpande, J.V. and Purohit S.G. (2005). Life Time Data: Statistical Models and Methods, Word Scientific.
- Tobias, P.A. and Trindane, D. C. (1995). Applied Reliability. Second edition. CRC Press.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU6103

Course Name: Lab course on 23ScStaU6101 & 23ScStaU6102

Teaching Scheme: 4 Hours/Week

Credit: 2

Examination Scheme: CIA: 20 Marks

End-Sem : 30 Marks

Prerequisites: Theory of estimation and distribution theory .

Course Objectives: Students are expected to learn

- Sampling schemes via SRSWR, SRSWOR for both qualitative and quantitative type variables,
- Stratified random sampling and cost and variance analysis in it.

Course Outcomes: After completion of the course students are enabled to apply sampling scheme to real life data sets.

Course Content:

Sr. No.	Title of experiment	No. of Practical
1	Simple random sampling (estimation of population mean, population total with standard errors), i) with replacement, ii) without replacement. Confidence interval for population mean and population total	1
2	Stratified Random Sampling: Proportional and Neyman allocation, comparison with SRSWOR	1
3	Cost and Variance Analysis in Stratified Random sampling.	1
4	Designing a questionnaire, Data Reliability testing by using a) Kuder Recharadson Coefficient (KR-20) b) Cronbach's Coefficient Alpha	1
5	R chart, $\bar{X}$ chart I	1
6	p-chart (for fixed and variable sample size)	1
7	Single sampling plan for attributes: OC curve, AOQ, AOQL, ATI using Poisson approximation	1
8	Determination of single sampling plan for attributes by i) Lot Quality Approach ii) Average Quality Approach	1
9	Classification of life time distributions	1
10	Non-parametric survival analysis.	1
11	Data Mining: unsupervised learning.	1
12	Data Mining: Supervised learning I	1
13	Data Mining: Supervised learning II	1
14-15	Experiential learning	2

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU6201

Course Name: Design of Experiments (T)

Teaching Scheme: 2 Hours/Week

Credit : 2

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisites:

- Basic concepts from linear algebra and probability distributions.
- Concept of linear regression model.

Course Objective:

- To understand concepts of design of experiments and apply it to real life data.

Course Outcome: After completion of the course students will able to learn

1. Concept of Basic design like CRD, RBD and LSD.
2. Analysis data collected from CRD, RBD and LSD.
3. Concept and analysis of covariance models.
4. how to compare the pairs of treatment means using different methods.
5. analysis of factorial experiments.
6. To Apply appropriate model and analysis tool for real life data.

Course Content:

Unit	Title and content	Lectures
Unit 1	Design of Experiments	18
	1.1 Analysis of variance (ANOVA): concept and technique.	
	1.2 Basic terms of design of experiments: Experimental unit, treatment, layout of an experiment.	
	1.3 Basic principles of design of experiments: Replication, randomization and local control. Choice of size and shape of a plot for uniformity trials, the empirical formula for the variance per unit area of plots.	
	1.4 Completely Randomized Design (CRD) : Application of the principles of design of experiment in CRD, Layout, Model: (Fixed effect)	

	$X_{ij} = \mu + \alpha_i + \varepsilon_{ij}$ $i = 1, 2, \dots, t ; j = 1, 2, \dots, n_i$ assumptions and interpretations. Breakup of total sum of squares with respect to components. Estimation of parameters, Testing normality of residuals graphically, expected values of mean sums of squares, components of variance, preparation of (ANOVA) table, testing equality of treatment effects, procedure to test the hypothesis $H_0 : \alpha_1 = \alpha_2 = \dots = \alpha_t = 0$ Comparison of treatment means using box plot techniques. Statement of Cochran's theorem. F test for testing H_0 with justification (independence of chi-square is to be assumed), test for equality of two specified treatment effects using critical difference (C.D). 1.5 Randomized Block Design (RBD) : Application of the principles of design of experiments in RBD, layout Model (Fixed Effects) $X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$ $i = 1, 2, \dots, t ; j = 1, 2, \dots, b$ Assumptions and interpretations. Breakup of total sum of squares into components. Estimation of parameters, Testing normality of residuals graphically, expected values of mean sums of squares, components of variance, preparation of analysis of variance table, Hypotheses to be tested $H_{01} : \alpha_1 = \alpha_2 = \dots = \alpha_t = 0$ $H_{02} : \beta_1 = \beta_2 = \dots = \beta_b = 0$ F-test for testing H_{01} and H_{02} with justification (independence of chi-squares is to be assumed), test for equality of two specified treatment effects using critical difference(CD). 1.6 Latin Square Design (LSD): Application of the principles of design of experiments in LSD, layout, Model : (Fixed Effects) $X_{ij(k)} = \mu + \alpha_i + \beta_j + \gamma_k + \varepsilon_{ij(k)}$ $i = 1, 2, \dots, m \quad j = 1, 2, \dots, m \text{ and}$ $k = 1, 2, \dots, m$ Assumptions and interpretations. Breakup of total sum of squares into components. Estimation of parameters, Testing normality of residuals graphically , expected values of mean sums of squares, components of variance, preparation of analysis of variance table, hypotheses to be tested. $H_{01} : \alpha_1 = \alpha_2 = \dots = \alpha_m = 0$ $H_{02} : \beta_1 = \beta_2 = \dots = \beta_m = 0$ $H_{03} : \gamma_1 = \gamma_2 = \dots = \gamma_m = 0$ and their interpretation. Justification of F test for H_{01}, H_{02} and H_{03} (independence of chi-square is to be assumed). Preparation of ANOVA table and F test for H_{01},	
--	--	--

	H_{02} and H_{03} testing for equality of two specified treatment effects, comparison of treatment effect using critical difference, linear treatment contrast and testing its significance. 1.7 Linear contrasts, orthogonal contrast, Scheffe's method for comparing contrasts, Tuckey's procedure for comparing pair of treatment means (applicable to C.R.D. ,R.B.D. and L.S.D.) 1.8 Identification of real life situations where the above designs are used.	
Unit 2	Analysis of Covariance (ANOCOVA) with One Concomitant Variable	06
	2.1 Situations where analysis of covariance is applicable. 2.2 Model for covariance in CRD Estimation of parameters (derivations are not expected) Preparation of analysis of variance – covariance table, test for $\beta = 0$, test for equality of treatment effects (computational technique only).	
Unit 3	Design and Analysis of Factorial Experiments	06
	3.1 General description of m^n factorial experiment, 2^2 and 2^3 factorial experiments arranged in RBD. 3.2 Definitions of main effects and interaction effects in 2^2 and 2^3 factorial experiments. Yate's procedure, preparation of ANOVA table, test for main effects and interaction effects.	
References: 1. Cochran W.G. and Cox, C.M. (1968) Experimental Design, John Wiley and Sons, Inc., New York. 2. Dass, M.N. and Giri,N.C. (1986) Design and Analysis of Experiments, II Edition Wiley Eastern Ltd., New Delhi 3. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. 4. Goon, A.M., Gupta, M.K. and Dasgupta, B. (1998). Fundamentals of Statistics, Vol. II, The world Press Pt. Ltd. Kolkata 5. Gupta S.C. and Kapoor V.K. (2006). Fundamentals of Applied Statistics, S. Chand Sons, New Delhi 6. Johnson, R.A., Miller, I. and Freund, J. (2010). Probability and Statistics for engineers, Prentice Hall, India. 7. Montgomery, D.C. (2001). Design and Analysis of Experiments, John Wiley and sons Inc., New Delhi. 8. Snedecor, G.W. and Cochran, W.G. (1994). Statistical Methods, 8th edition, Affiliated East West Press, New Delhi 9. Wu, C.F.J. and Hamda, M. (2009). Experiments, Planning, Analysis and Parameter Design Optimization, John Wiley & Sons, Inc. Hoboken, New Jersey.		

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU6201

Course Name: Design of Experiments (P)

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA:20 Marks

End-Sem: 30 Marks

Prerequisites:

- Statistical Inference, Distribution theory.

Course Objectives: Students are expected to learn

1. Analysis of variance techniques for CRD, RBD and LSD.
2. Analysis of covariance techniques for CRD, RBD and LSD.
3. Analysis of factorial experiments.

Course Outcomes: After completion of the course students are enabled to apply DOE techniques to real life data sets.

Course Content:

Sr. No.	Title of experiment	Number of Practicals
1	Planning a lay out and analysis of C.R.D. I (checking adequacy of the model)	1
2	Analysis of C.R.D.II (checking normality assumption, Efficiency, Duncan's, Tuckey's and Fisher's LSD , Scheffe's method)	1
3	Analysis of R.B.D. I	1
4	Analysis of R.B.D. II (checking normality assumption, Efficiency, Duncan's, Tuckey's and Fisher's LSD , Scheffe's, method)	1
5	Analysis of L.S.D. I	1
6	Analysis of L.S.D. II (checking normality assumption, Efficiency, Duncan's, Tuckey's and Fisher's LSD Scheffe's method)	1
7	Analysis of non-normal data-I using Kruskal -Wallis Test	1
8	Analysis of non-normal data-II (Using Transformations)	1
9	Analysis of covariance in C.R.D.-I	1
10	Analysis of covariance in C.R.D.-II	1
11	Analysis of 2^2 factorial experiments in R.B.D.	1
12	Analysis of 2^3 factorial experiments in R.B.D.	1
13-15	Experiential learning	3

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code: 23ScStaU6202

Course Name: Operations Research (T)

Teaching Scheme: 2 Hours/Week

Credit:02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisite Courses:

- Basic concepts of linear algebra.
- Basic concepts of matrix operations and systems of linear equations.
- Graphical method.

Course Objectives: On completion of the course, student will be able

- To understand various methods of operational research to obtain optimum solutions and apply it to real life data.
- To understand the concept of duality in linear programming.

Course Outcomes: At the end of the course the students will be able to:

1. Formulate real-life optimization problems.
2. Apply various method of linear programming model and obtain optimum solution.
3. Solve a primal problem by using its dual problem, demonstrating the interrelationship between the two.
4. Apply various method of transportation model and obtain the optimum solutions.
5. Apply various method of assignment model and obtain the optimum solutions.
6. Apply various methods of operational research to obtain optimum solutions and apply it to real life data.

Course Contents:

Unit 1	Linear Programming	20
	1.1 Statement of the linear Programming Problem (LPP),(minimization and maximization) Formulation of problem as L.P. problem. Definition of (i) A slack variable, (ii) A surplus Variable. L.P. Problem in (i) Canonical form ,(ii) standard form. Definition of (i) a solution (ii) basic and non basic variables (iii) a feasible solution (iv) a basic feasible solution, (v) a degenerate and non-degenerate solution (vi) an optimal solution. 1.2 Solution of L.P.P. by graphical method , Solution of L.P.P by Simplex Method: Obtaining Initial Basic Feasible Solution (IBFS) , criteria for deciding whether obtained solution is optimal ,criteria for unbounded solution , no solution , more than one solutions , introduction of artificial variable, Big-M method. 1.3 Two Phase method 1.4 Duality Theory: Writing dual of a primal problem, solution of a L.P.P. by using its dual problem. 1.5 Examples and problems.	
Unit 2	Problems of Transportation and Assignment	10
	2.1 Transportation problem (T.P.), statement of T.P., balanced and unbalanced T.P. Minimization and maximization problem. 2.2 Obtaining basic feasible solution of T.P. by (i) Least cost method (ii) Vogel's approximation method (VAM). 2.3 u-v (MODI) method of obtaining Optimal solution of T.P., uniqueness and non- uniqueness of optimal solutions, degenerate solution 2.4 Assignment Problem (A.P.) : Statement of an assignment problem , Minimization and maximization problem , balanced and unbalanced problem ,relation with transportation problem , optimal solution using Hungarian method , maximization case, prohibited A.P. 2.5 Examples and problems.	

References:	
1.	Gass, S.L. (1997). Linear programming methods and applications, Narosa Publishing House, New Delhi.
2.	Gupta, P.K. and Hira, D.S.(2008). Operation Research, 3 rd edition S. Chand and company Ltd., New Delhi.
3.	Kapoor, V. K.(2006). Operations Research, S. Chand and Sons. New Delhi.
4.	Phillips, D.T and Solberg, R.A.(1976). Operation Research principles and practice, John Willey and sons Inc.
5.	Saceini, M., Yaspan,A.. and Friedman, L.(2013). Operation Research methods and problems, Willey International Edition.
6.	Sharma, J.K. (1989). Mathematical Models in Operation Research, Tata McGraw Hill Publishing Company Ltd., New Delhi.
7.	Shrinath.L.S (1975). Linear Programming, Affiliated East-West Pvt. Ltd, New Delhi. 8. Taha, H.A. (2007). Operation research: An Introduction, eighth edition, Prentice Hall of India, New Delhi.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020

Course Code :23ScStaU6202

Course Name: Operations Research (P)

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisite Courses:

- Basic concepts of linear algebra.
- Graphical method.

Course Objectives: On completion of the course, student will be able to

- To understand various methods of operational research to obtain optimum solutions and apply it to real life data.
- To understand the concept of duality in linear programming.

Course Outcomes: At the end of the course the students will be able to:

1. Formulate real-life optimization problems.
2. Apply various method of linear programming model and obtain optimum solution.
3. Solve a primal problem by using its dual problem, demonstrating the interrelationship between the two.
4. Apply various method of transportation model and obtain the optimum solutions.
5. Apply various method of assignment model and obtain the optimum solutions.
6. Apply various methods of operational research to obtain optimum solutions and apply it to real life data.

Course Contents:

Sr. No.	Title of Experiment/ Practical
1	Formulate the linear programming problem (LPP).
2	Solving LPP using graphical method (Cases: feasible solution ,infeasible solution, no solution, unbounded solution, alternate solution)
3	Solving LPP using simplex method (Cases: feasible solution ,infeasible solution)

4	Solving LPP using simplex method (Cases: unbounded solution, alternate solution)
5	Solving LPP using Big-M method.
6	Solving LPP using Two phase method.
7	Finding dual of given primal problem and solution it.
8	Formulate Transportation problem (TP)and Find initial basic feasible solutionusing least cost method, Vogel's approximation method.
9	Finding Optimal solution of TP using modified distribution method.
10	Finding Optimal solution of TP using modified distribution method (in case of degeneracy occurs.)
11	Problems on CPM
12	Problems on Sequencing
13-15	Experiential learning

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020(Minor)

Course Code: 23ScStaU6301

Course Name: Applied Statistics II (T)

Teaching Scheme: 2 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisite Courses: Basic probability and probability distribution

Course Objectives:

- To understand different method of analyzing time series data.
- To understand various method of hypothesis testing.
- To understand ANOVA technique.

Course Outcomes: On completion of the course, student will be able

1. To study time series with its component.
2. To estimate and eliminate trend and seasonality from time series.
3. To learn concept of hypothesis testing.
4. To apply an appropriate test for testing means and proportions.
5. To learn ANOVA technique.
6. To apply ANOVA technique for real life situation.

Course Contents

Unit 1	Time Series	10
	1.1 Introduction, Definition, Components of Time Series 1.2 Methods of estimating Trends: least square (linear and second degree), Moving averages (with periods 3,4,5), Exponential smoothing, 1.3 Method of estimating seasonality: simple average method 1.4 cyclical variation: definition, distinction from seasonal variation. 1.5. Irregular variation: definition, illustration	
Unit 2	Testing of hypothesis	15
	2.1 Definitions of: Hypothesis, Null hypothesis, Alternating hypothesis, Critical region, Types of Errors, Level of significance, P-value.	

	2.2 Test for Population Mean (Approximate and Exact tests): Describe test procedure for testing i. $H_0: \mu = \mu_0$ against $H_1: \mu \neq \mu_0$ and ii. $H_0: \mu_1 = \mu_2$ against $H_1: \mu_1 \neq \mu_2$ If population variance is known. mean and difference of population means 2.4 Describe the test procedure for paired t-test. 2.5 Test for population proportion : Describe test procedures for testing i. $H_0: P = P_0$ against $H_1: P \neq P_0$ and ii. $H_0: P_1 = P_2$ against $H_1: P_1 \neq P_2$. 2.6 Describe Chi-square test for testing i. Goodness of fit. ii. Independence of attributes. 2.7 Describe test procedure for testing $H_0: \sigma_1^2 = \sigma_2^2$ against $H_1: \sigma_1^2 \neq \sigma_2^2$ (test based on F-distribution)	
Unit 3	Analysis of variance	5
	Concept and technique of one way and two-way ANOVA, examples and problems.	

References:

1. Goon, A. M., Gupta, M. K. and Dasgupta, B. (2016). Fundamentals of Statistics, Vol. 1, 6th Revised Edition, The World Press Pvt. Ltd., Calcutta.
2. Goon A. M., Gupta, M. K. and Dasgupta, B. (1986), Fundamentals of Statistics, Vol. 2, World Press Kolkata.
3. Gupta S.C., Kapoor V.K. (2014). Fundamentals of Mathematical Statistics, Sultan Chand & Sons publication, Delhi Gupta S.C. (2018). Fundamentals of Statistics: Himalaya Publishing House
4. Gupta, S. C. and Kapoor, V. K. (2000). Fundamentals of Mathematical Statistics, 10th Edition, Sultan Chand and Sons Publishers, New Delhi.
6. Hogg, R. V. and Craig, A. T., McKean J. W. (2012), Introduction to Mathematical Statistics (Tenth Impression), Pearson Prentice Hall.
7. Mohanty (2016). Basic Statistics, Scientific Publisher
8. Mukhopadhyay P. (2015). Applied Statistics, Publisher: Books & Allied (P) Ltd.

Progressive Education Society's
Modern College of Arts, Science and Commerce,
Shivajinagar, Pune - 5
Third Year of B.Sc. (NEP 2023)
Course under NEP 2020(Minor)

Course Code: 23ScStaU6301(P)

Course Name: Applied Statistics (P)

Teaching Scheme: 4 Hours/Week

Credit: 02

Examination Scheme: CIA: 20 Marks

End-Sem: 30 Marks

Prerequisite Courses: Basic Mathematics.

Course Objectives:

- To apply different method of analyzing time series data.
- To apply various method of hypothesis testing.
- To apply ANOVA technique.

Course Contents

Sr. No.	Title of Experiment/ Practical
1	Estimation and elimination of trend component using least square method.
2	Estimation and elimination of trend component using Moving average method.
3	Estimation and elimination of trend component exponential smoothing method.
4	Estimation of seasonal indices by simple average method.
5	Application of approximate sample test-I
6	Application of approximate sample test-II
7	Application of exact sample test.
8	Tests based on chi-square distribution.
9	Tests based on F distribution.
10	Application of one-way ANOVA
11	Application of two-way ANOVA
12	Project work (equivalent to 4 practical)

—X—X—X—