Deccan Education Society's

Fergusson College (Autonomous), Pune

Learning Outcomes-Based Curriculum
for 3/4 years B. Sc. /B. Sc. (Honours)
Programme as per guidelines of

NEP-2020: 1.0

for

T. Y. B. Sc. (Statistics)

With effect from Academic Year
2025-2026

Deccan Education Society's

Fergusson College (Autonomous), Pune-4

Department of STATISTICS

Syllabi NEP 1.0 Implemented from Academic Year 2025-26

T.Y. B.A./BSc Semester : V/VI

Program Specific Outcomes (PSOs)

PSO	Outcomes
PSO1	**Academic competence:** (i) Recall summary statistics for quantitative and qualitative data, basic concepts of probability, infinite series, concepts of financial mathematics for actuarial statistics. (ii) Understand concept of correlation and regression, multiple regression, probability distributions and their characteristic properties, some standard discrete and continuous probability models, theory of inference.
PSO2	**Personal and Professional Competence:** (i) Simulate various probability distributions using various random number generation procedures. (ii) Apply the statistical techniques that involve exploratory and confirmatory data analysis to the real life data collected through sample surveys, and prepare project reports.
PSO3	**Research Competence:** Plan statistical designing of experiments ,learn its applications and analysis, learn modelling and analysis of time series data ,forecasting of time series, create life tables and decide life insurance policy premiums , learn modelling of different probability distributions , use of R-software for statistical analysis.
PSO4	**Entrepreneurial and Social competence:** Employ the process of thinking independently, taking initiative, working in a team effectively, preparing project reports and developing capability to lead the team through real life projects.

T.Y. B.A./B.Sc. NEP 1.0						
Semester	Paper	Paper Code	Title	Type	Credits	Exam Type
V	Major	STS-301	Distribution Theory	Theory	2	CE+ESE
		STS-302	Theory of Estimation	Theory	2	CE+ESE
		STS-303	Design of Experiment	Theory	2	CE+ESE
	Elective	STS-304 OR STS-305	Introduction to Regression Analysis OR Statistical Ecology	Theory	2	CE+ESE
				Theory	2	CE+ESE
		STS -306 OR STS-307	Operations Research OR Biostatistics	Theory	2	CE+ESE
				Theory	2	CE+ESE
	Major	STS-311	Statistics Practical-5	Practical	2	CE+ESE
		STS-312	Statistics Practical-6	Practical	2	CE+ESE
	VSC	STS-331	Actuarial Statistics	Theory	2	CE
		STS-332	Statistics Practical-7	Practical	2	CE
	Minor	STS-321	Introduction to Statistical Hypothesis Testing	Theory	2	CE+ESE
	FP	STS-345	Field Project	Theory / Practical	2	CE
	BA (Minor)	STS-324	Introduction to tests of Hypotheses	Theory	4	CE+ESE
VI	Major	STS-351	Testing of Hypotheses	Theory	2	CE+ESE
		STS-352	Applied Multivariate Analysis	Theory	2	CE+ESE
		STS-353	Introduction to Stochastic Processes	Theory	2	CE+ESE
	Elective	STS-354 OR STS-355	Introduction to Survival Analysis OR Operation Management	Theory	2	CE+ESE
				Theory	2	CE+ESE
		STS-356 OR STS-357	Elements of Statistical Computing and Data Mining OR Demography and Official Statistics	Theory	2	CE+ESE
				Theory	2	CE+ESE
	Major	STS-361	Statistics Practical-8	Practical	2	CE+ESE
		STS-362	Statistics Practical-9	Practical	2	CE+ESE
	VSC	STS-382	Statistics Practical-10	Practical	2	CE
	Minor	STS-371	Statistical Techniques-III	Theory	2	CE+ESE
	OJT	STS-395	OJT	Theory / Practical	4	CE
	BA (Minor)	STS-374	Sampling Methods and its Applications	Theory	4	CE+ESE

T. Y. B Sc. SEM V		
	STS-301-Distribution Theory **Major - Theory**	
	Number of Credits: 02 **No. of Hours: 30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define various continuous probability distributions and outline the properties of probability density functions, cumulative distribution functions.	1
CO2	Compute moment generating function, raw moments, central moments of different continuous probability distributions.	2
CO3	Demonstrate the significance of the distributions and identify the real life situations for probability distributions.	3
CO4	Analyse the relationship between different continuous distributions using the nature of the distributions.	4
CO5	Determine and develop problem-solving techniques needed to accurately calculate probabilities.	5
CO6	Relate the probability distributions to real life situations	6

STS-301-Distribution Theory
(Major- Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Gamma Distribution** 1.1 The probability density function (p.d.f) $f(x) = \frac{\alpha^{\lambda}}{\lambda} e^{-\alpha x} x^{\lambda-1}$, $x \geq 0$, $\lambda>0$, $\alpha>0$ $= 0$ Otherwise Notation : $X \sim G(\alpha, \lambda)$ α : scale parameter, λ : shape parameter, Nature of probability curve for various values of shape parameter , m.g.f., c.g.f., moments, cumulants, $\beta 1$, $\beta 2$, γ_1, γ_2 , mode, additive property, Erlang distribution as a special case of gamma distribution, Distribution of sum of n iid exponential variables with same scale parameter.	**[05]**

2	**Weibull Distribution** 2.1 The probability density function (p.d.f. $$f(x)=\frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{(\beta-1)}\exp\left\{-\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right\} \quad , x\geq\gamma, \quad \alpha,\beta>0$$ $$=0 \qquad \text{otherwise}.$$ Notation: X~W(γ,α,β). 2.2 Probability curve, location parameter, shape parameter, scale parameter. Derivation of distribution function, quartiles, mean and variance, coefficient of variation, relationship with gamma and exponential distribution. Application of this model for real life data.	**[04]**
3	**Cauchy Distribution:** 3.1 The probability density function (p.d.f.) $$f(x)=\frac{\lambda}{\pi}\frac{1}{\lambda^2+(x-\mu)^2} \quad , -\infty<x<\infty, -\infty<\mu<\infty, \lambda>0.$$ Notation: X~C(μ,λ). 3.2 Nature of the probability curve, comparison with tails of normal distribution, 3.3 Derivation of distribution function, quartiles. Non – existence of moments, Statement of distribution of aX+b. Derivation of distribution of i) $\frac{1}{X}$ ii) X^2 ,where X ~ C (0,1), Problems based on these results. 3.4 Statement of additive property for two Independent Cauchy variates, statement of distribution of the sample mean, comment on limiting distribution of $\overline{X}$. 3.5 Statement of relationship with uniform, student's t and normal distributions. Application of this model for real life data.	**[06]** ગ
4	**Laplace (Double Exponential) Distribution:** 4.1 The probability density function (p.d.f.) $$f(x)=\frac{\lambda}{2}\exp(-\lambda\lvert x-\mu\rvert), \quad -\infty<x<\infty, -\infty<\mu<\infty, \lambda>0.$$ Notation: X ~ L (μ , λ) Nature of probability curve. 4.2 Derivation of distribution function, quartiles. 4.3 MGF, CGF, Moments and cumulants, skewness and kurtosis. 4.4 Derivation of Laplace distribution as the distribution of the difference of two i.i.d. exponential random variables with mean $\frac{1}{\lambda}$. Application of this models for real life data.	**[06]**
5	**Lognormal Distribution:** 5.1 The probability density function (p.d.f.)	**[05]**

	$f(x) = \frac{1}{(x-a)\sigma\sqrt{2\pi}} \exp\{\frac{-1}{2\sigma^2}[\log_e(x-a)-\mu]^2$, $x > a$, $, -\infty < \mu < \infty, \sigma > 0.$ $= 0$ otherwise. Notation : X~ LN (a, μ , σ^2) 5.2 Derivation of relation with N (μ, σ^2) distribution. 5.3 Nature of the probability curve. 5.4 Derivation of moments (r^{th} moment of X), mean, variance, Karl Pearson's and Bowley's coefficient of skewness. Coefficient of kurtosis, derivation of quartiles and mode. 5.5 Distribution of $\pi_{i=1}^{n} X_i$ when Xi's are independent lognormal random variables. Application of this model for real life data.	
6	**Order statistics:** 6.1 Order Statistics for a random sample of size from a continuous distribution, definition, derivation of distribution function and density function of the i^{th} order statistics $X_{(i)}$, particular cases fir I = 1 and i = n. Joint distribution of $(X)_{(i)}$, $(X)_{(i)}$ for a random sample from uniform and exponential distribution. Definition of p^{th} sample quantile X[(np]+1). Distribution of sample median for a random sample from uniform distribution .	**[04]**

Learning Resources- References

Sr. No.	References
1.	Hogg, R.V. and Craig A.T.(1978). Introduction to Mathematical Stastistics, IVth Edition, Macmillan Publishing Company.Inc. New York.
2.	Lindgren B.W.: (1976) Statistical Theory III rd Edition Collier Macmillan international Edition, Macmillan Publishing Co. Inc. New York.
3.	Mood. A.M., Graybill , F.Bose ,D.C.: (1974) Introduction to theory of Statistics. III rd Edition Mc- Graw Hill Series.
4.	Mukhopdhyay, P (1996). Mathematical Statistics, New Central Book Agency.
5.	Rohatgi , V.K. IIIrd Edition An Introduction to probability Theory and Mathematical Statistics Wiley Eastern Ltd .New Delhi.
6.	Casella G. and Berger Robert L. (2002) Statistical Inference. 2nd Edition, Duxbury Advanced series.
7.	Dasgupta A. (2010) Fundamentals of Probability : A first course, Springer, New York.

	STS-302-Theory of Estimation **Major - Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe various terms for point estimation, interval estimations to understand problem of statistical inference. List and study the properties of point estimators.	1
CO2	Explain the method to obtain estimators using maximum likelihood, method of moments, method of scoring and Fisher Information function.	2
CO3	Demonstrate different situations with random sample from the standard distributions to obtain appropriate estimators. Execute the method to construct confidence intervals.	3
CO4	Compare different estimators with random sample from the standard distributions with unknown parameters and examine the suitability of estimators.	4
CO5	Evaluate efficiency of estimators and justify the importance of Fisher information function.	5
CO6	Build the importance of an estimator of unknown parameter through various situations.	6

STS-302-Theory of Estimation
(Major - Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Point Estimation** 1.1 Notion of a parameter, parameter space, sample space as a set of all possible values of $(X_1, X_2, \ldots, X_n)$, general problem of estimating an unknown parameter by point and interval estimation. Notion of a parameter, parameter space, sample space as a set of all possible values of $(X_1, X_2, \ldots, X_n)$, general problem of estimating an unknown parameter by point and interval estimation. 1.2 Mean Square Error (MSE) of an estimator.	**[03]**
2	**Methods of Estimation:** 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 distributions ii) continuous distributions, 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 only standard distributions (case of two unknown parameters only for normal distribution). Use of iterative procedure to derive M.L.E. of location parameter μ of Cauchy distribution. Invariance property of M.L.E.	**[03]**

	2.4 M.L.E. of θ in uniform distribution over i) (0, θ) ii) (- θ, θ), iii) (mθ, nθ) (m<n) M.L.E. of θ in f(x;θ) = $e^{-(x-\theta)}$; x > θ M.L.E. of location parameter in Laplace distribution, Illustrations of situations where M.L.E. and moment estimators are distinct and their comparison using mean square error.	
3	**Properties of estimators.** **3.1 Unbiasedness** Definition of an unbiased estimator, 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 ø (T) is unbiased estimator of ø (θ) provided ø (.) is a linear function. **3.2 Variance of the estimator** Notion of the Best Linear Unbiased Estimator and uniformly minimum variance unbiased estimator (UMVUE), uniqueness of UMVUE whenever it exists. Illustrations, **3.3 Sufficiency** Concept and definition of sufficiency, statement of the Fisher-Neyman factorization theorem with proof for discrete probability distribution. Pitmann – Koopman form and sufficient statistic; Exponential family of probability distributions and sufficient statistic. Proofs of the following properties of sufficient statistic: i) If T is sufficient for θ, then ø (T) is also sufficient for θ provided ø is a one to one and onto function. ii) If T is sufficient for θ then T is also sufficient for ø (θ). iii) M.L.E. is a function of sufficient statistic **3.4 Efficiency** Fisher information function: Amount of information contained in statistic T=T (X_1, X_2, …, X_n). Statement regarding information in sample and in a sufficient statistic T. Cramer- Rao Inequality: Statement and proof of Cramer - Rao inequality, Cramer – Rao Lower Bound (CRLB), definition of minimum variance bound unbiased estimator (MVBUE) of ø(θ). Proofs of following results: a) If MVBUE exists for θ then MVBUE exists for ø (θ) where ø is a linear function. b) If T is MVBUE for θ then T is sufficient for θ, Comparison of variance with CRLB, relative efficiency of T_1 w.r.t. T_2 for (i) unbiased (ii) biased estimators, Efficiency of unbiased estimator T w.r.t. CRLB. **3.5 Asymptotic Behaviour of an Estimator** Consistency: Definition, proof of the following theorems: 1. An estimator is consistent if its bias and variance both tend to zero as the sample size tends to infinity. 2. If T is consistent estimator of θ and ø (.) is a continuous function, then ø (T) is a consistent estimator of ø (θ)	**[19]**

4	**4.1 Interval Estimation** 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. 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) iii) Median, quartiles using order statistics.	**[05]**

Learning Resources- References

Sr. No.	References
1.	Dudewicz, E.J. and Mishra, S.N. (1988). Modern Mathematical Statistics, John Wiley, New York.
2.	Hoel, P.G. Port, S. and Stone, C.(1972). Introduction to Statistical Theory, Houghton Mifflin Company (International) Dolphin Edition.
3.	Hogg, R.V. , McKean and Craig, A.T. (2019). Introduction to Mathematical Statistics (Eighth edition), Pearson.
4.	Mood, A.M., Graybill, F. and Bose, D.C. (1974). Introduction to the theory of Statistics (third edition) International Student Edition, McGraw Hill.
5.	Rohatagi , V.K. (2015). An introduction to Probability Theory and Mathematical Statistics, Wiley Eastern Ltd., New Delhi.
6.	C.Radhakrishna Rao, (2009). Linear Statistical Inference and its Applications, (Second edition)
7.	Kale B.K. and Murlidharan K. (2016) Introduction to Parametric Inference , Narosa Publication House, New Delhi.

	STS-303-Design of Experiment **Major - Theory**	
	Number of Credits: 02 **No. of Hours: 30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Identify relationships between cause and effect, planning and designing the experiments.	1
CO2	Outline interactions among causative factors through factorial experiments.	2
CO3	Apply different experimental designs to real life situations.	3
CO4	Analyse collected information through the experiments planned according to different designs using ANOVA and ANCOVA techniques.	4
CO5	Validate the design employed in real life situations using residual analysis.	5
CO6	Design a lay out of different statistical designs.	6

STS-303: Design of Experiment
(Major - Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**1.1 Analysis of variance (ANOVA):** concept and technique, Basic terms of design of experiments: Experimental unit, treatments, layout of an experiment. 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. **1.2 Completely Randomized Design (CRD):** Application of the principles of design of experiment in CRD, Layout, Model: $X_{ij} = \mu + \alpha_i + \varepsilon_{ij}$ i= 1,2, …….t. j = 1,2,……., n_i, Assumptions and interpretations. Breakup of total sum of squares into components. Estimation of parameters, expected values of mean sums of squares, components of variance, preparation of (ANOVA) table, testing equality of treatment effects, hypothesis to be tested $H_0 : \alpha_1 = \alpha_2 = \cdots = \alpha_m = 0$. Statement of Cochran's theorem. F test for testing $H_o$with justification (independence of chi-square is to be assumed), test for equality of two specified treatment effects using critical difference (C.D). **1.3 Randomized Block Design (RBD):** Application of the principles of design of experiments in RBD, Layout, Model: $X_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$ i= 1,2, ……. t. j = 1, 2… b, assumptions and interpretations, Breakup of total sum of squares into components. Estimation of parameters, expected values of mean sums of squares, components of variance, preparation of analysis of variance table, Hypotheses to be tested,	**[16]**

	H_{01}:$\alpha_1 = \alpha_2 = \alpha_3 = \ldots = \alpha_t = 0$ H_{02} : $\beta_1 = \beta_2 = \beta_3 = \ldots = \beta_b = 0$, 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). **1.4 Latin Square Design (LSD):** Application of the principles of design of experiments in LSD, layout Model : $X_{ij(k)} = \mu + \alpha_i + \beta_j + Y_k + \varepsilon_{ij(k)}$, i = 1.2 … m, j = 1, 2 …, m, k = 1, 2 …., m. Assumptions and interpretations. Break up of total sum of squares into components. Estimation of parameters, expected values of mean sum of squares, components of variance, preparation of ANOVA table, hypothesis to be tested H_{01}: $\alpha_1 = \alpha_2 = \cdots = \alpha_m = 0$, H_{02} : $\beta_1 = \beta_2 \cdots = \beta_m = 0$, H_{03} : $\gamma_1 = \gamma_2 = \cdots = \gamma_m = 0$, and their interpretations, 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 effects using critical difference, linear treatment contrast and testing its significance, Linear treatment contrasts, orthogonal contrasts. Scheffe's method for comparing contrasts, Tukey's procedure for comparing pairs of treatment means (applicable to C.R.D., R.B.D. and L.S.D.), Identification of real life situations where the above designs are used and their analysis.	
2	**Efficiency of Design** 2.1 Concept and definition of efficiency of a design. 2.2 Efficiency of RBD over CRD. 2.3 Efficiency of LSD over (i) CRD (ii) RBD.	**[03]**
3	**Analysis of Covariance (ANOCOVA) with One Concomitant Variable** 3.1 Model for covariance in CRD. Estimation of parameters (derivations are not expected). 3.2 Preparation of analysis of variance – covariance table, test for $\beta=0$, test for equality of treatment effects (computational technique only)	**[03]**
4	**Factorial Experiments** 4.1 General description of mn factorial experiment, 2^2 and 2^3 factorial experiments arranged in RBD. 4.2 Definitions of main effects and interaction effects in 2^2 and 2^3 factorial experiments. 4.3 Yate's procedure, preparation of ANOVA table, test for main effects and interaction effects. 4.4 General idea of confounding in factorial experiments. 4.5 Construction of layouts in total confounding and partial confounding in 2^2 and 2^3 factorial experiments. 4.6 Total confounding (confounding only one interaction) ANOVA table, testing main effects and interaction effects. 4.7 Partial confounding (confounding only one interaction per replicate); ANOVA table, testing main effects and interaction effects.	**[08]**

Learning Resources- References

Sr. No.	References
1.	Cochran W.G. and Cox, C.M. (1992) 2nd Edition Experimental Design, John Wiley and Sons, Inc., New York.
2.	Dass, M.N. and Giri,N.C. (2020) Design and Analysis of Experiments, IIIrd Edition Wiley Eastern Ltd., New Delhi.
3.	Federer W.T. (1977) Experimental Design : Oxford and IBH Publishing Co., New Delhi.
4.	Goon, A.M., Gupta,M.K. and Dasgupta, B. (2016). Fundamentals of Statistics, Vol.II, The world Press Pvt. Ltd. Kolkata.
5.	Johnson, R.A., Miller, I. and Freund, J.(2011). Probability and Statistics for engineers, Prentice Hall, India.
6.	Montgomery, D.C. (2019). Design and Analysis of Experiments, 10th John Wiley and sons Inc., New Delhi.
7.	Snedecor, G.W. and Cochran, W.G. (1994). Statistical Methods

	STS-304-Introduction to Regression Analysis **Elective – Theory**	
	Number of Credits: 02 **No. of Hours: 30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the concept of fitting of simple regression models.	1
CO2	Articulate the concept of multicollinearity.	2
CO3	Compare residual diagnostics and apply corrective measures.	3
CO4	Analyse the multiple linear regression and logistic regression models.	4
CO5	Justify weighted least squares method.	5
CO6	Determine tests of hypothesis of model parameters, AIC and BIC criteria.	6

STS-304-Introduction to Regression Analysis
Elective – Theory

Unit No.	Title of Unit and Contents	No. of hours
1	**Simple linear regression model:** 1.1 Review of simple linear regression model: $Y = \beta_0 + \beta_1 X + \varepsilon$ where ε is a continuous random variable with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma^2$ .Estimation of β_0 and β_1, by the method of least squares. 1.1 Properties of estimators of β_0, and β_1. 1.2 Estimation of σ^2. 1.3 Assumption of normality of ε. Tests of hypothesis of β_1. 1.4 Interval estimation in simple linear regression model. 1.5 Coefficient of determination. 1.6 Residual analysis: Standardized residuals, Studentized residuals, residual plots. 1.7 Detection and treatment of outliers. 1.8 Interpretation of four plots produced by lm command in R	**[8]**
2	**Multiple linear regression model:** 2.1 Review of multiple linear regression model $Y = \beta_0 + \beta_1 X_1 + \ldots + \beta_p X_p + \varepsilon$, where ε is a continuous random variable with $E(\varepsilon) = 0$, $V(\varepsilon) = \sigma^2$ Estimation of regression parameters $\beta_0, \beta_1, \ldots$ and β_p by the method of least squares, obtaining normal equations, solutions of normal equations. 2.2 Estimation of σ^2. 2.3 Assumption of normality of ε . Tests of hypothesis of regression parameters. 2.4 Interval estimation in multiple linear regression model. 2.5 Methods of variable selection variable selection and model building. 2.6 Residual diagnostics and corrective measures such as transformation of	**[14]**

	response variable, weighted least squares method. 2.7 Introduction of multicollinearity, computation of VIF. 2.8 Polynomial regression models	
3	**Logistic regression model** 3.1 Binary response variable, Logit transform, estimation of parameters, interpretation of parameters. 3.2 Tests of hypotheses of model parameters, model deviance, LR test. 3.3 AIC and BIC criteria for model selection. 3.4 Interpretation of output produced by glm command in R 3.5 Multiple logistic regression**.**	**[8]**

Learning Resources- References

Sr. No.	References
1.	Draper, N. R. and Smith, H. (1998). Applied Regression Analysis Third Edition, John Wiley.
2.	Hosmer, D. W. and Lemeshow, S. (2013). Applied Logistic Regression, Wiley. Third Edition
3.	Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012). Introduction to Linear Regression Analysis Wiley. Fifth Edition
4.	Neter, J., W., Kutner, M. H., Nachtsheim, C.J. and Wasserman, W. (2005): Applied Linear Statistical Models, fifth edition, Irwin USA.
5.	Chatterjee S. and Hadi A.S. (2012): Regression Analysis by Example, 5th Edition,Wiley.
6.	Kleinbaum G. and Klein M. (2011) : Logistic Regression, IIIrd

	STS-305-Statistical Ecology **Elective - Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Memorize the components of life table.	1
CO2	Compare fitted growth models.	2
CO3	Summarize smoothing procedures to estimate population density.	3
CO4	Solve differential equations for population growth models.	4
CO5	Judge the quality of fitted growth models.	5
CO6	Develop different indices to measure biodiversity.	6

STS-305-Statistical Ecology
(Elective – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Population Dynamics:** 1.1 Introduction: Ecology, Statistical Ecology. 1.2 Linear Growth $dNt/dt = C$, Interpretation and limitation. 1.3 Exponential Model: Solving $dNt/dt = KNt$, $K > 0, K<0$ cases. Properties, Interpretation, Scope and Limitation. 1.4 Logistic growth model: Density dependence, solving differential equation 1.5 $dNt/dt = a.Nt (K-N t)$Properties ,carrying Capacity, Interpretation, Scope and Limitation. 1.6 Geompertz Curve: Solving Differential equation $dNt/dt = a. \log (K/N t)$, Asymptotically stable Equilibrium, Properties, Interpretation, Scope and Limitation. Fitting the above growth models to data by linearization and regression. 1.7 Life tables: Force of mortality stable population and stationary population. Cohort, columns of life table, interrelation between columns interpretation, construction of life table, uses and application.	**[10]**

2	**Smoothing Procedures:** 2.1 Poisson forest, Aggregated, Regular spatial point pattern, estimation of Population, density by quadrate sampling, nearest neighbor distances (Point to individual, individual to individual), i^{th} order nearest neighbor distance. $\lambda = \frac{n}{\prod x_i^2}$ mle for Poisson forest, Bias and S.E. of λ estimate. 2.2 Line transect method: Drawing random line transect, exponential detection function, mle of population density, other detection functions. 2.4 Capture –recapture models: Closed population, Open population, Peterson estimator for single recapture, Multiple captures, irative method to find mle of N, Population size. 2.3 Removal method : Zippin's estimator for closed population.	**[10]**
3	**Diversity Indices:** 3.1 Concept of Biodiversity, need to protect it. 3.2 Richness indices, Simpson's index, Shannon's index. 3.3 Rare fraction Curves, Real life examples for computing these indices.	**[05]**
4	**Distribution Models:** 4.1 Use of geometric distribution, lognormal distribution in ecology.	**[05]**

Learning Resources- References

Sr. No.	References
1.	Pielou,E.C.(1977):An Introduction to Mathematical Ecology, Wiley.
2.	Seber,G.A.F.(1982): The estimation of animal abundance and related parameters, C. Griffin.
3.	Ludwig,J.A. and Regnold J.F.: Statistical Ecology, A primer on methods and computing.
4.	Gore,A.P. and Prajpe, S.A. : A First Course on mathematical and Statistical Ecology.

	STS-306-Operations Research **Elective – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the concept of linear programming.	1
CO2	Represent a given situation into LPP and formulate the objective function , constraints and the network diagram.	2
CO3	Apply the techniques of solving LPP to obtain optimal solution.	3
CO4	Classify the solutions and interpret them according to the situations.	4
CO5	Evaluate the CPM and PERT networks and apply project crashing techniques.	5
CO6	Devise cost benefit analysis for different projects.	6

STS-306-Operations Research
(Elective - Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Linear Programming:** 1.9 Statement of the linear Programming Problem (LPP) with minimization or maximization of objective function. 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 (i) Graphical method (ii) 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. 1.1 Duality Theory: Writing dual of a primal problem, solution of a L.P.P. by using its dual problem.	**[07]**
2	**Transportation Problem:** 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. Removing degeneracy and obtaining optimal solution. 2.4 Assignment Problem: Statement of an assignment problem,	**[11]**

	Minimization and maximization problem, balanced and unbalanced problem, relation with transportation problem, optimal solution using Hungarian method, maximization case**.**	
3	**Critical Path Method (CPM) and Project Evaluation and Review Techniques (PERT):** 3.1 Definition of (i) Event, (ii) Node, (iii)Activity, (iv)Critical Activity, (v)Project Duration 3.2 CPM: Construction of network, Definitions, (i) earliest start time. (ii) earliest finish time. (iii) latest start time. (iv) latest finish time for an activity, Critical Path, Types of float, total floats, free float, independent float and their significance. Determination of critical path. 3.3 PERT: Construction of network; (i) Pessimistic time estimate, (ii) Optimistic time estimate (iii) Most likely time estimates, Determination of critical path, determination of mean and standard deviation of project duration computations of probability of completing the project in a specified duration. 3.4 Cost Benefit Analysis: Definition of normal time, crash time, normal cost, crash cost, cost slope, direct cost, indirect cost, project cost, Determination of project duration and its associated cost when (i) Normal time are considered. (ii) Crash time are considered, Determination of optimal network.	**[12]**

Learning Resources- References

Sr. No.	References
1.	Gass, S.L. (2011). *Linear programming methods and applications*, Fifth Edition Dover Publications Inc.
2.	Gupta, P.K. and Hira, D.S. *Operation Research*, 7th edition S. Chand and company Ltd., New Delhi.
3.	Kapoor, V. K. (2006). *Operations Research*, S. Chand and Sons. New Delhi.
4.	Saceini, M., Yaspan,A. and Friedman, L.(2013). *Operation Research methods and problems,* Willey International Edition.
5.	Sharma, J.K. (1989). *Mathematical Models in Operation Research*, Tata McGraw Hill Publishing Company Ltd., New Delhi.
6.	Shrinath.L.S (1975). *Linear Programming*, Affiliated East-West Pvt. Ltd, New Delhi.
7.	Taha, H.A. (2017). *Operation research: An Introduction,* 10th edition, Prentice Hall of India, New Delhi

	STS-307-Biostatistics **Elective - Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall concepts of health, illness, disease and socially defined concept of sickness and define the phases of clinical trials.	1
CO2	Discuss the principles of epidemiology.	2
CO3	Demonstrate the types of study designs used in clinical trials and use of randomization and blinding.	3
CO4	Analyze 2 x 2 cross over design data	4
CO5	Evaluate proportional odds ratio.	5
CO6	Write the objectives of clinical trials.	6

STS-307-Biostatistics
(Elective – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Epidemiology:** 1.1 Introduction to Epidemiology, cross-sectional designs, longitudinal designs 1.2 Odds, odds ratio, relative risk , cohort studies , case control studies 1.3 Estimation of odds ratio (OR), Confidence interval for OR. Relation with parameter in a logit model. 1.4 Chi square test of independence of attributes, Symmetry in square contingency tables, Mcnemar test, Bowker test, collapsing tables and Simpson's paradox. 1.5 Incidence rate, prevalence rate, Crude mortality rate, Specific Mortality Rates	**[08]**
2	**Clinical trials:** 2.1 General information on history of drug discovery including Louis Pasteur (rabies and small pox), Ronald Ross and malaria, Alexander Fleming and penicillin, Jonas Salk and polio, cholera, asthma, diabetes, blood pressure, heart attack, arthritis. 2.2 Phases of clinical trial, purpose, duration, cost, drug regulatory bodies, ICH, statistical analysis plan, clinical study report , case report forms 2.3 Randomized controlled trials , 2.4 Blinding (single blinding , double blinding)	**[06]**
3	**Design of clinical trials:** 3.1 Objectives and end points of clinical trials, 3.2 Parallel designs , cross-over designs, factoria design, design of phase I trials, design of single – stage and multi-stage phase II trials. Design and monitoring of phase III trials with sequential stopping, 3.3 Determination of sample size i) One sample , variance known ii) Two independent samples , variance known	**[10]**

4	**Bioequivalence and bio-availability:** 4.1 Concept of Bioequivalence 4.2 Concept of bio-availability, absolute bioavailability 4.3 Pharmacokinetic parameters , drug plasma concentration Vs time plot ,Area under the Curve (AUC), Cmax , Tmax , $t_{1/2}$, washout period 4.4 Statistical criteria for assessment of bioequivalence	**[06]**

Learning Resources- References

Sr. No.	References
1.	A.p .Gore and S. A, Paranjape ,(2000) *Course on mathematical and statistical Ecology*, Kluwer, publishing Holland.
2.	M.B. Kulkarni, V.R. Prayag, (2004) "*Introduction to Statistical Ecology, SIPF Academy*, Nasik 41.
3.	Agresti A. (1996) *Categorical Data Analysis*. Wiley, New York.
4.	J.N.S. Matthews (2006) *Introduction to Randomized Controlled clinical Trials*, Chapman and Hall.
5.	Stephen Sann (2000) *Statistical Issues in drug Development*, John Wiley.
6.	Steven Diantadosi (2000) *Clinical Trials – A methodological Perspective*, John Wiley.
7.	L.M. Friedmon, C.D. Forbes, D.L. Demats (2000) *Fundamentals of Clinics Trials*, Spinner.
8.	Steve selvin (2004) *Epidemiologic Analysis*, Oxford Press.
9.	M.M. Shoukni, C.A. Pavse (1999) *Statistical Methods for Health Sciences*, CPC Pree.
10.	Steve Salvin, (1999) *Statistical Analysis of Epidemiologic Data*, Oxford.
11.	Leon Gordis (2000) , *Epidemiology* 2nd edition , W.B.Saunders Company

	STS-311-Statistics Practical-5 **Major - Practical**	
	Number of Credits: 02 **No. of Hours:60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the theory of continuous distributions.	1
CO2	Carry out model sampling from Cauchy and Laplace distributions. Also carry out fitting of lognormal distribution	2
CO3	Construct confidence intervals for order statistics. Apply theory of continuous distributions to compute probability of various events	3
CO4	Analyze the Regression models.	4
CO5	Compare different distributions for real life situations.	5
CO6	Develop method to obtain MLE of location parameter of Cauchy distribution.	6

Statistics Practical-5
(Major – Practical)

Unit No.	Title of Unit and Contents	No. of hours
1	Model sampling from Cauchy and Laplace distributions	4
2	Fitting of lognormal distribution.	4
3	MLE of location parameter μ of Cauchy distribution.	4
4	Applications of gamma distribution	4
5	Applications of Weibull distribution	4
6	Applications of lognormal distribution	4
7	Applications of Laplace distribution.	4
8	Constructions of confidence intervals of μ and σ^2 of Lognormal distribution.	4
9	Construction of confidence interval for population median and quartiles, based on order statistics.	4
10	Simple linear regression analysis.	4
11	Fitting of Multiple linear regression model.	4
12	Testing hypotheses and interval estimation of regression parameters in multiple linear regression model.	4
13,14&15	Applications of the above distributions to realistic data sets.	12

Note: The practicals on experiment number10 to 12 are according to the major elective paper.

Learning Resources- References

Sr. No.	References
1.	Hogg, R.V. and Craig A.T.(1978). Introduction to Mathematical Statistics, IVth Edition, Macmillan Publishing Company .Inc. New York
2.	Mood. A.M. , Graybill , F.Bose ,D.C.: (1974) Introduction to theory of Statistics. III rd Edition Mc- Graw Hill Series.
3.	Rohatgi , V.K. IIIrd Edition An Introduction to probability Theory and Mathematical Statistics Wiley Eastern Ltd .New Delhi.
4.	Casella G. and Berger Robert L. (2002) Statistical Inference. 2nd Edition, Duxbury Advanced series.
5.	Dasgupta A. (2010) Fundamentals of Probability : A first course,Springer, New York.

	STS-312-Statistics Practical-6 **Major - Practical**	
	Number of Credits: 02 **No. of Hours:60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the principles of design of Experiments and planning of experiments.	1
CO2	Illustrate the layout of designs employed.	2
CO3	Apply parametric and non-parametric methods of analysis of variance.	3
CO4	Analyse various experimental designs.	4
CO5	Interpret the output of analysis of various statistical designs.	5
CO6	Hypothesize the objectives in the given practical situation to employ a specific experimental design.	6

STS-312-Statistics Practical-6
Major - Practical

Unit No.	**Title of Unit and Contents**	**No. of hours**
1	Planning a layout and analysis of CRD	**4**
2	Analysis of R.B.D. ,	**4**
3	Analysis of LSD.	**4**
4	Multiple comparison (pairwise comparison) of treatment means using critical difference (C.D.), Scheffe's procedure in case of CRD, Tukey's method of pairwise comparison in case of CRD (for equal replications only).	**4**
5	Multiple comparison (pairwise comparison) of treatment means using critical difference (C.D.), Tukey and Scheffe's procedure in case of RBD	**4**
6	Multiple comparison (pairwise comparison) of treatment means using critical difference (C.D.), Tukey and Scheffe's procedure in case of LSD.	**4**
7	Efficiency of RBD w.r.t. CRD, efficiency of LSD w.r.t. i) CRD ii) RBD.	**4**
8	Analysis of covariance in CRD, testing $\beta = 0$.	**4**
9	Analysis of 2^2 and 2^3 factorial experiments in CRD.	**4**
10	Analysis of 2^2 and 2^3 factorial experiments in RBD.	**4**
11	Analysis of 2^3 factorial experiments in RBD (Total confounding).	**4**
12	Analysis of 2^3 factorial experiments in RBD (partial confounding).	**4**
13,14&15	Case Studies	**12**

Learning Resources- References

Sr. No.	References
1.	Cochran W.G. and Cox, C.M. (1992) 2nd Edition *Experimental Design*, John Wiley and Sons, Inc., New York.
2.	Dass, M.N. and Giri,N.C. (2020) *Design and Analysis of Experiments,* IIIrd Edition Wiley Eastern Ltd., New Delhi.
3.	Federer W.T. (1977) *Experimental Design* : Oxford and IBH Publishing Co., New Delhi.
4.	Goon, A.M., Gupta,M.K. and Dasgupta, B. (2016). *Fundamentals of Statistics, Vol.II,* The world Press Pvt. Ltd. Kolkata.
5.	Johnson, R.A., Miller, I. and Freund, J.(2011). *Probability and Statistics for engineers,* Prentice Hall, India.
6.	Montgomery, D.C. (2019). *Design and Analysis of Experiments,* 10th John Wiley and sons Inc., New Delhi.
7.	Snedecor, G.W. and Cochran, W.G. (1994). *Statistical Methods,* Wiley-Blackwell; 8th edition

	STS-331-Actuarial Statistics **VSC – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the concepts of financial mathematics and probability theory.	1
CO2	Explain terms used in insurance business and survival analysis.	2
CO3	Calculate actuarial present values and amount of premium for insurance policy.	3
CO4	Classify risks into pure and speculative risk.	4
CO5	Compare statistical distributions of life length random variable on the basis of survival curves and force of mortality curves.	5
CO6	Construct life tables for different age groups of people.	6

STS-331-Actuarial Statistics
(VSC – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Insurance Business:** 1.1 Insurance companies as business organizations. 1.2 Role of insurance business in Economy. 1.3 Concept of risk, types of risk, characteristics of insurable risk. 1.4 Working of insurance business, introduction of terms such as premium, policy, policyholder and benefit. 1.5 Role of Statistics in insurance. 1.6 Insurance business in India. 1.7 Measurement of adverse financial impact, expected value principle. 1.8 Concept of utility function. 1.9 Feasibility of insurance business. 1.10 Illustrative examples**.**	**[05]**
2	**Survival Distribution and Life Tables:** 2.1 Time- until death random variable, its distribution function and survival function in actuarial notation, 2.2 Force of mortality, 2.3 Interrelations among distribution function, survival function, force of mortality and probability density function, 2.4 Curtate future life random variable, its probability mass function and survival function in actuarial notation, 2.5 Construction of life table.	**[10]**
3	**Models for Life Insurance and Annuities:** 3.1 Theory of compound interest, effective rate of interest, discount factor. 3.2 Insurance payable at the end of the year of death, present value random variable, actuarial present value. 3.3 Derivation of actuarial present value for n-year term life insurance, whole life insurance and endowment insurance, 3.4 Annuities – certain, annuity due, annuity immediate,	**[08]**

	3.5 Discrete life annuities: n-year temporary life annuity due and a whole life annuity due, present value random variables of the payment, and their actuarial present values.	
4	**Benefit Premiums:** 4.1 Concept of a loss random variable, 4.2 Equivalence principle, 4.3 Computation of fully discrete premium for n-year term life insurance, whole life insurance and endowment insurance, 4.4 Variance of loss random variable.	**[06]**

Learning Resources- References

Sr. No.	References
1.	Bowers N.L. Jr., H.S.Gerber, J.C. Hickan, D.A.Jones, C.J.Nesbitt, (1997). Actuarial Mathematics, Society of Actuaries, U.S.
2.	Deshmukh, S. R. (2010). 3rd revised edition Actuarial Statistics, Universities Press, Hyderabad, India.

	STS-332-Statistics Practical-7 **VSC – Practical**	
	Number of Credits: 02 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the concept of Linear Programming, financial mathematics and probability theory.	1
CO2	Articulate different types of linear programming problem. Explain the concept of survival function and its properties.	2
CO3	Apply the techniques to find optimal solution to all types of LPP. Calculate actuarial present values and amount of premium for insurance policy.	3
CO4	Compare statistical distributions of life length random variable.	4
CO5	Determine and interpret the optimal solutions of all types of LPP	5
CO6	Construct life tables for various age groups of people.	6

STS-332: Statistics Practical-7
(VSC – Practical)

Unit No.	Title of Unit and Contents	No. of hours
1	Expected value principle and computation of minimum acceptable premium using utility function	**4**
2	Survival function and force of mortality	**4**
3	Distributions of future life time and curtate future lifetime random variable	**4**
4	Construction of life tables	**4**
5	Computation of APV for different insurance products and Discrete Annuities.	**4**
6	To formulate real life situation into LPP, To obtain optimal solution of LPP by Simplex method.	**4**
7	To obtain optimal solution of Primal LPP from dual LPP.	**4**
8	Transportation Problem-I	**4**
9	Transportation Problem-II	**4**
10	To obtain optimal solution of assignment problem.	**4**
11	Critical path Analysis	**4**
12	Cost Benefit Analysis	**4**
13,14&15	Case Study	**12**

Note: The practicals on experiment number 6 to 12 are according to the major elective paper.

Learning Resources- References

Sr. No.	References
1.	Bowers N.L. Jr., H.S.Gerber, J.C. Hickan, D.A.Jones, C.J.Nesbitt, (1997). Actuarial Mathematics, Society of Actuaries, U.S.
2.	Deshmukh, S. R. (2010). 3rd revised edition Actuarial Statistics, Universities Press, Hyderabad, India.
3.	Sharma, J.K. (1989). Mathematical Models in Operation Research, Tata McGraw Hill Publishing Company Ltd., New Delhi.
4.	Taha, H.A. (2017). Operation research: An Introduction, 10^{th} edition, Prentice Hall of India, New Delhi

	STS-321-Introduction to Statistical Hypothesis Testing **Minor – Theory**	
	Number of Credits: 02 **No. of Hours: 30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define statistic and sampling distribution	1
CO2	Discuss and define the terms used in testing of hypotheses, Demonstrate the various situations for testing using exact tests, large sample tests and small sample tests, Articulate the concept of non-parametric tests.	2
CO3	Apply the tests for real life problems and discuss the conclusions, Compute probabilities of type I and type II error, p value.	3
CO4	Examine the suitability of the tests to be applied and inference to be drawn.	4
CO5	Decide the appropriate hypotheses for testing the population parameters like mean, variance, correlation, proportion.	5
CO6	Develop the concept of analysis of variance techniques, Construct the tests about various population parameters and test goodness of fit of probability distributions.	6

STS-321-Introduction to Statistical Hypothesis Testing
(Minor – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Tests of significance** 1.1 Notion of a statistic as a function $T(X_1, X_2, ..., X_n)$ and its illustrations. 1.2 Sampling distribution of $T(X_1, X_2, ..., X_n)$. Notion of standard error of a statistic. 1.3 Notion of hypothesis, critical region, level of significance. 1.4 Tests based on normal distribution for (i) $H_0 : \mu = \mu_0$ against $H_1 : \mu \neq \mu_0$, $\mu < \mu_0$, $\mu > \mu_0$ (ii) $H_0 : \mu_1 = \mu_2$ against $H_1 : \mu_1 \neq \mu_1$, $\mu_1 < \mu_2$, $\mu_1 > \mu_2$ (iii) $H_0 : P = P_0$ against $H_1 : P \neq P_0$, $P < P_0$, $P > P_0$ (iv) $H_0 : P_1 = P_2$ against $H_1 : P_1 \neq P_2$, $P_1 < P_2$, $P_1 > P_2$	**[4]**

2	**Tests based on t, chi-square and F distributions** 2.1 Definition of t variate, p.d.f. of t_n distribution, nature of probability curve Computation of probability of different events using t distribution probability tables Tests for population mean based on t distribution (i) $H_0 : \mu = \mu_0$ against $H_1 : \mu \neq \mu_0 , \mu < \mu_0 , \mu > \mu_0$ (ii) $H_0 : \mu_1 = \mu_2$ against $H_1 : \mu_1 \neq \mu_1 , \mu_1 < \mu_2 , , \mu_1 > \mu_2$ (iii) Paired observations 2.2 Definition of Chi square variate , p.d.f. of Chi square distribution, nature of probability curve, Computation of probability of different events using Chi square distribution probability tables, Tests based on Chi square distribution: Tests for $H_0: \sigma^2 = \sigma_0^2$ against $H_1: \sigma^2 \neq \sigma_0^2 , \sigma^2 > \sigma o^2 , \sigma^2 > \sigma_0^2$ Chi square test for independence of attributes: Chi square test for independence of r x s contingency- table. Test of goodness of fit. 2.3 Definition of F variate, p.d.f. of $F(n_1, n_2)$ distribution, nature of probability curve, Computation of probability of different events using $F(n_1, n_2)$ distribution probability tables, Tests for variance: To test $H_0: \sigma_1^2 = \sigma_2^2$ against $H_1: \sigma_1^2 \neq \sigma_2^2, \sigma_1^2 < \sigma_2^2, \sigma_1^2 > \sigma_2^2$	**[18]**
3	**Analysis of variance** 3.1 Concept of analysis of variance. 3.2 One-way classification: break up of total sum of squares, analysis of variance table, test of hypotheses of equality of several means using analysis of variance technique, pairwise testing of equality of treatment means. 3.3 Numerical problems.	**[8]**

Learning Resources- References

Sr. No.	References
1.	Goon, Gupta and Dasgupta (1968): Fundamentals of Statistics,Vol. I, The World Press Pvt. Ltd. Calcutta.
2.	Gupta, S. P.(2014) : Statistical Methods, Sultan Chand and Sons, Delhi.
3.	GuptaS.C., and Kapoor V.K.(1994) : Fundamental s of Applied Statistics , Sultan Chand & n Sons,Delhi
4.	Hoel, P. G.(1965): Introduction. of Mathematical Statistics, John Wiley and Sons Co. New York.
5.	Larson H.J.(1982): Introduction to Probability Theory and statistical Applications, A Wiley International Edition
6.	Meyer, P. L. (1970): Introductory Probability Theory and Statistical Applications, Addison-Wesley Publishing Company.
7.	Walpole, R.E. (1982):Introduction to Statistics, Macmillan Publishing Co. New York

	STS-345: Field Project **FP - Theory/Practical**	
	Number of Credits: 02 **No. of Hours: 60**	

<table>
<tr><th>Unit No.</th><th>Title of Unit and Contents</th><th>No. of hours</th></tr>
<tr><td>1</td><td>
<table>
<tr><td colspan="2">Foundations of Field Work (1 credit)</td></tr>
<tr><td>Topics Covered</td><td>Activities</td></tr>
<tr><td>Field visits, Field work Reflection and Analysis</td><td>- Reflective journals on field experiences
- Group presentations</td></tr>
<tr><td>Community Impact Assessment</td><td>- Methods for assessing project impact
- Group project: Conduct impact assessment in a chosen community</td></tr>
<tr><td colspan="2">Advanced Field Work (1 credit)</td></tr>
<tr><td>Topics Covered</td><td>Activities</td></tr>
<tr><td>Field Work, Project Presentation
Review and Integration</td><td>- Review of key concepts from previous credits
- Integration of community engagement and fieldwork principles
- Analysis
- Submission of CEP/FP project report</td></tr>
</table>
<u>Evaluation:</u>
Evaluate each student for 50 marks per semester at department level –
20 marks for Continuous evaluation (CE)
Progress report on project implementation. (Field diary)
30 marks for End Semester Examination (ESE)
Project Report
Final presentation of field project findings assessing project outcomes and reflections.
UGC Recommended field-based activities:
1. Interaction with Self Help Groups (SHGs) women members, and study their functions and challenges; planning for their skill-building and livelihood activities;
2. Visit Mahatma Gandhi National. Rural Employment Guarantee Act 2005 (MGNREGS) project sites, interact with beneficiaries and interview functionaries at the work site;
3. Field visit to Swachh Bharat project sites, conduct analysis and initiate problem solving measures;
4. Conduct Mission Antyodaya surveys to support under Gram Panchayat
</td><td></td></tr>
</table>

	Development Plan (GPDP); 5. Interactive community exercise with local leaders, panchayat functionaries, grass-root officials and local institutions regarding village development plan preparation and resource mobilization; 6. Visit Rural Schools/mid-day meal centres, study academic and infrastructural resources, digital divide and gaps; 7. Participate in Gram Sabha meetings, and study community participation; 8. Associate with Social audit exercises at the Gram Panchayat level, and interact with programme beneficiaries; 9. Visit to local Nagarpalika office and review schemes for urban informal workers and migrants; 10. Attend Parent Teacher Association meetings, and interview school dropouts; 11. Visit local Anganwadi Centre and observe the services being provided; 12. Visit local NGOs, civil society organisations and interact with their staff and beneficiaries; 13.Organize awareness programmes, health camps, Disability camps and cleanliness camps; 14. Conduct soil health test, drinking water analysis, energy use and fuel efficiency surveys and building solar powered village; 15. Raise understanding of people's impacts of climate change, building up community's disaster preparedness; 16. Organise orientation programmes for farmers regarding organic cultivation, rational use of irrigation and fertilizers, promotion of traditional species of crops and plants and awareness against stubble burning; 17. Formation of committees for common property resource management, village pond maintenance and fishing; 18. Identifying the small business ideas (handloom, handicraft, khadi, food products,etc.) for rural areas to make the people self-reliant. 19. Any other Community engagement activity with approval of BOS and Academic Council. (Note that every department can also find CEP allied with their subject.)	

	STS-324-Introduction to Tests of Hypotheses **Minor – Theory (B.A.)**	
	Number of Credits: 04 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define the basic terms related to introduction of testing of Hypothesis.	1
CO2	Demonstrate the various situations for testing using exact tests. The large sample tests and small sample tests are also demonstrated.	2
CO3	Apply the tests for real life problems and discuss the conclusions.	3
CO4	Examine the suitability of the tests to be applied and inference to be drawn.	4
CO5	Evaluate Probability of type I error, power of the test. And p value.	5
CO6	Develop the concept of analysis of variance techniques.	6

STS-324-Introduction to Tests of Hypotheses
(Minor – Theory) (B.A.)

Unit No.	Title of Unit and Contents	No. of hours
1	**Tests of significance** 1.1 Notion of a statistic as a function $T(X_1, X_2, ..., X_n)$ and its illustrations. Sampling distribution of $T(X_1, X_2, ..., X_n)$. Notion of standard error of a statistic. 1.2 Notion of hypothesis, critical region, level of significance Tests based on normal distribution for (i) $H_0 : \mu = \mu_0$ against $H_1 : \mu \neq \mu_0$, μ μ_0 (ii) $H_0 : \mu_1 = \mu_2$ against $H_1 : \mu_1 \neq \mu_1$, $\mu_1 < \mu_2$, $\mu_1 > \mu_2$ (iii) $H_0 : P = P_0$ against $H_1 : P \neq P_0$, $P < P_0$, $P > P_0$ (iv) $H_0 : P_1 = P_2$ against $H_1 : P_1 \neq P_2$, $P_1 < P_2$, $P_1 > P_2$	**[09]**
2	**Tests based on t, chi-square and F distributions:** 2.1 t tests for (i) $H_0 : \mu = \mu_0$ against $H_1 : \mu \neq \mu_0$, $\mu < \mu_0$, $\mu > \mu_0$ (ii) $H_0 : \mu_1 = \mu_2$ against $H_1 : \mu_1 \neq \mu_1$, $\mu_1 < \mu_2$, , $\mu_1 > \mu_2$ (iii) Paired observations Tests for $H_0 : \sigma^2 = \sigma_0^2$ against $H_1 : \sigma^2 \neq \sigma_0^2$, $\sigma^2 > \sigma_o^2$, $\sigma^2 > \sigma_0^2$ 2.2 Chi square test for independence of attributes: Chi square test for independence of r x s contingency- table (without proof). Yate's correction not expected. Tests for $H_0 : \sigma_1^2 = \sigma_2^2$ against H1 : $\sigma_1^2 \neq \sigma_2^2$, $\sigma_1^2 < \sigma_2^2$, $\sigma_1^2 > \sigma_2^2$	**[19]**

3	**Analysis of variance techniques:** 3.1 Concept of analysis of variance. 3.2 One-way and two – way classification: break up of total sum of squares, analysis of variance table. 3.3 Test of hypotheses of (i) equality of several means, (ii) equality of two means 3.4 Numerical problems.	**[09]**
4	**Non - parametric tests.** 4.1 Distinction between a parametric and non-parametric problem. 4.2 Concept of distribution free statistics. 4.3 One tailed and two tailed test procedure of (a) Sign test, (b) Wilcoxon's signed rank test, run test, kruskal- Wallis test, Mann-Witney test.	**[17]**
5	**Tests based on chi-square distribution:** a) Test for independence of two attributes arranged in rs contingency table. b) Test for 'Goodness of Fit'	**[6]**

Learning Resources- References

Sr. No.	References
1.	Goon, Gupta and Dasgupta (1968): Fundamentals of Statistics,Vol. I, The World Press Pvt.Ltd. Calcutta.
2.	Gupta, S. P.(2014) : Statistical Methods, Sultan Chand and Sons, Delhi.
3.	GuptaS.C., and Kapoor V.K.(1994) : Fundamentals of Applied Statistics , Sultan Chand & Sons,Delhi.
4.	Hoel, P. G.(1965): Introduction. of Mathematical Statistics, John Wiley and Sons Co. New York.
5.	Larson H.J.(1982): Introduction to Probability Theory and Statistical Applications, A Wiley International Edition.
6.	Meyer, P. L.(1970): Introductory Probability Theory and Statistical Applications, Addison-Wesley Publishing Company.
7.	Walpole, R.E. (1982):Introduction to Statistics, Macmillan Publishing Co. New York

T. Y. B Sc. SEM VI		
	STS-351-Testing of Hypotheses **Major – Theory**	
	Number of Credits: 02 **No. of Hours: 30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the terms involved in the problem of testing hypotheses to develop MP and UMP tests.	1
CO2	Compute Type I error and Type II error to understand the concept of MP and UMP tests.	2
CO3	Demonstrate MP test using NP Lemma and construction of LRT and SPRT	3
CO4	Explain the situations when UMP test exists	4
CO5	Justify the use of parametric or non-parametric tests.	5
CO6	Develop a Likelihood Ratio Test and illustrate that the MP test is a special case of LRT.	6

STS-351: Testing of Hypotheses
(Major – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Most Powerful tests:** 1.1 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. 1.2 Power function of a test, power curve, definition of uniformly most powerful (UMP) level α test for one sided alternative. Illustrations.	**[07]**
2	**Likelihood ratio test (LRT):** 2.1 $\lambda(x) = Sup_{\theta \epsilon \Theta 0} £(\theta \mid x) / Sup_{\theta \epsilon \Theta 0 \cup \Theta 1} £(\theta \mid x)$ Construction of LRT for $H_0 : \theta = \theta_0$ against $H_1 : \theta \neq \theta_0$ for the mean of normal distribution for i) known σ^2 ii) unknown σ^2 (one sided and two sided alternatives). LRT for variance of normal distribution for i) known μ ii) unknown μ (one sided and two sided alternatives hypotheses). LRT for parameters of binomial and exponential distribution for two sided alternatives only. LRT as a function of sufficient statistics, statement of asymptotic distribution of $-2 \log_e \lambda(x)$ for testing $H_o : \theta \in$ Ho again $H_1 : \theta \in H_1$.	**[08]**

3	**Sequential Tests:** 3.1 Wald's Sequential probability test procedure of strength (α, β) for simple null hypothesis of against simple alternative hypothesis and its comparison with fixed sample size N-P test procedure. Definition of Wald's SPRT of strength (α, β). Illustration for standard distributions like Bernoulli, Exponential. SPRT test statistic as a function of sufficient statistics. Graphical representation of SPRT.	**[8]**
4	**Non-parametric Tests** 4.1 Concept of non- parametric tests. Distinction between parametric and nonparametric tests. Concept of distribution free statistics. One tailed and two tailed test procedure of Run test, one sample and two sample problems. 4.2 Empirical distribution function $S_n(x)$, Properties of $S_n(x)$ as estimator of F (.). Kolmogorov – Smirnov test for completely specified univariate distribution (one Sample problem only) for two sided alternative hypotheses. Comparison with chi-square test.	**[7]**

Learning Resources- References

Sr. No.	References
1.	Daniel, W.W. (2000): Applied Nonparametric Statistics, 2nd edn. Duxbury Press Boston.
2.	Dudeweitz, E.J. and Mishra, S.N. (1988): Modern Mathematical Statistics, John Wiley and Sons, Inc
3.	Gibbons J.D.(2010): Non parametric Statistical Inference, 5th edn. CRC Press Book.
4.	Hogg, R.V. and Craig, R.G. (1989): Introduction to Mathematical Statistics, fourth edition,.Collier Macmillan International Edition, Macmillan Publishing Co. Inc., New York.
5.	Kale, B.K. and Muralidharan, K. (2015): Parametric Inference: An Introduction. Narosa, New Delhi.
6.	Mood, A.M., Graybill, F. and Bose, D. C .(1974) : Introduction to the theory of Statistics, third edition International Student, Edition, McGraw Hill.
7.	Rohatgi, V.K. (2008) : An introduction to Probability Theory Statistics, Wiley Eastern Ltd., New Delhi.

	STS-352-Applied Multivariate Analysis **Major – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Memorize the properties of univariate normal distribution. Define bivariate and multivariate distributions.	1
CO2	Demonstrate the significance of the distributions and identify the real-life situations for bivariate and multivariate distributions.	2
CO3	Construct probability density curves for bivariate distribution.	3
CO4	Determine and develop problem-solving techniques needed to accurately calculate probabilities.	4
CO5	Apply discriminant analysis techniques for solving real-world events. Evaluate bivariate normality.	5
CO6	Construct clusters for data generated in day to day life using cluster analysis.	6

STS-352-Applied Multivariate Analysis
(Major – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Bivariate Normal Distribution** 1.1 Introduction of Univariate normal distribution: Review 1.2 Introduction of Bivariate normal distribution, its p.d.f. $f(x,y)=\frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}}\exp\{\frac{-1}{2(1-\rho^2)}[(\frac{x-\mu_1}{\sigma_1})^2+(\frac{y-\mu_2}{\sigma_2})^2-2\rho(\frac{x-\mu_1}{\sigma_1})(\frac{y-\mu_2}{\sigma_1})\}$ $-\infty<x,y<\infty,\ -\infty<\mu_1,\mu_2<\infty,\quad \sigma_1,\sigma_2>0,\ -1<\rho<1.$ $=0$ *otherwise.* Notation: $(X, Y) \sim BN(\mu_1, \mu_2, \sigma_1^2, \sigma_2^2, \rho)$. 1.3 Nature of surface of p. d. f., marginal and conditional probability distributions. 1.4 identification of parameters, regression of Y on X, independence and uncorrelatedness, 1.5 Derivation of MGF and moments. 1.6 Statement of distribution of aX+ bY+ c, $\frac{X}{Y}$ 1.7 Applications of this model for real life data.	**[09]**
2	**Multivariate Normal Distribution** 2.1 Introduction to Multivariate Normal Distribution, Non-singular Multivariate Normal Distribution. 2.2 Properties of Multivariate Normal Distribution (Statement only). 2.3 Applications of Multivariate Normal Distribution.	**[02]**
3	**Discriminant Analysis** 3.1Separation and classification for two populations. 3.2 Fisher's Approach to classification with two populations, Numerical	**[07]**

	examples. 3.3 Discriminant rule based on expected cost of misclassification. 3.4 Maximum likelihood estimation based discriminant rule. 3.5 classification with two multivariate normal populations. 3.6 Discriminant rule based on estimated cost of misclassification.	
4	**Cluster Analysis** 4.1 Distinction between discriminant and cluster analysis. 4.2 Hierarchical Clustering Methods: Single Linkage Method, Complete Linkage Method and Average Linkage Method. 4.3 Non-Hierarchical Clustering Method: K- means method. 4.4 Hierarchical Clustering Methods: Numerical examples. 4.5 Non-Hierarchical Clustering Method: Numerical examples.	**[08]**
5	**Principal Component Analysis** 5.1 Introduction to principal component analysis. 5.2 Population and sample principal components. 5.3 Variation explained by principal components. 5.4 Population and sample principal components: Numerical examples. 5.5 Scree plot.	**[04]**

Learning Resources- References

Sr. No.	References
1.	Anderson, T. W. (2003), Introduction to Multivariate Analysis, 3rd edition, John Wiley
2.	Morrison, D.F. (1990), Multivariate Statistical Methods, McGraw Hill Co.
3.	Rao, C. R. (2002). Linear Statistical Inference and its Applications, Paperback edition Wiley Eastern
4.	Timm, N. H. (2002), Applied Multivariate Analysis, Springer, New York
5.	Johnson R.A. & Wichern, D.W. (2007). Applied Multivariate Statistical Analysis, Sixth Edition, Prentice Hall Inc.

	STS-353-Introduction to Stochastic Processes **Major – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Describe the concepts of stochastic processes in discrete time, especially concerning Markov chains and their classifications.	1
CO2	Understand different types of stochastic processes and classify the states of Markov chain.	2
CO3	Demonstrate the computations of higher order probabilities of Markov chain.	3
CO4	Differentiate the stochastic processes based on classification of states	4
CO5	Explain the consent of stationary distribution of irreducible and ergodic Markov Chain.	5
CO6	Construct a one-step transition probability matrix for Markov chain.	6

STS-353: Introduction to Stochastic Processes
(Major – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Introduction** 1.1 Definition of a Stochastic process, state space, parameter space, types of stochastic processes, Markov chains (M.C.)$\{ X_n, n \geq 0\}$, finite M.C., time homogeneous M.C. 1.2 One step transition probabilities, and transition probability matrix (t.p.m.), stochastic matrix , graphical representation Markov chain, partial sum of independent and identically distributed random variables as Markov chain, n-step transition probability matrix. 1.3 Initial distribution, joint distribution function of $\{X_0, X_1, \ldots, X_n\}$, Chapman Kolmogorov equation, illustrations such as random walk, Gambler's ruin problem, partial sum of independent and identically distributed random variables as Markov chain, Ehrenfest chain.	**[12]**
2	**Classification of states** 2.1 Communicating states (accessible, transitive, symmetry, reflexive states), first return probability, probability of ever return 2.2 Classification of states, as persistent and transient states. Decomposition of state space, closed set of states, reducible state, reducible M.C., irreducible set of states, irreducible M.C., absorbing state, periodicity of M.C. aperiodic M.C., Mean recurrence, non-null recurrent, ergodic state, ergodic M. C. 2.3 Illustrate with random walk MC, Gambler's ruin MC, and other examples problem find is it ergodic MC or not.	**[09]**

3	**Stationary distribution** 3.1 Elementary property of stationary distribution, steady state distribution, 3.2 Stationary distribution for a reducible and irreducible ergodic finite long run behavior of a M.C.	**[05]**
4	**Poisson Process** 4.1 Postulates and properties of Poisson process, probability distribution of N(t), the number of occurrences of the event in (0, t], Poisson process and probability distribution of inter-arrival time ,mean, variance and covariance functions . 4.2 Definition of compound Poisson process mean and variance functions and its applications.	**[04]**

Learning Resources- References

Sr. No.	References
1.	Bhat, B.R. (2000): Stochastic models: Analysis and applications, New Age International.
2.	Hoel , P. G., Port, S.C. and Stone, C.J. (1972) :Introduction to stochastic processes, Wiley Eastern.
3.	Medhi J. (2009): Stochastic processes, New age International.
4.	Ross, S. (2014): Introduction to probability models, 11thedn, Elsevier.
5.	Ross, S. (1996): Stochastic processes, 2nd edn. John Wiley.
6.	Taylor, H N and Karlin, S. (2010): An introduction to stochastic modelling 4th edn. Academic Press.
7.	Vidyadhar Kulkarni (2016): Modelling and Analysis Stochastic Systems.3rd edn., CRC press.

	STS-354-Introduction to Survival Analysis **Elective - Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define the basic terms related to survival analysis. understand the survival function and its application	1
CO2	Demonstrate the concept of no ageing and its various classes of ageing.	2
CO3	Apply the suitable family of life distribution.	3
CO4	Compare the concept of censoring.	4
CO5	Evaluate the non-parametric estimation of survival function and develop its confidence interval	5
CO6	Develop the concept of Survival analysis and its applications.	6

STS-354-Introduction to Survival Analysis
(Elective – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Ageing** 1.1 Survival function, probability density function, hazard function, cumulative hazard rate, mean residual life function, equilibrium residual life function , interrelation between all these function, Total time on test transform (TTT). 1.2 No ageing, proof of following properties of no ageing 1) Cauchy functional equation 2) Constant failure rate 3) Constant mean residual life 4) Exponential life distribution 5) Exponential Equilibrium distribution 6) Identity function as the TTT transforms 1.3 Positive and negative ageing: IFR, DFR IFRA, DFRA, NBU, NWU, NBUE, NWUE, DMRL, IMRL, bathtub failure rate. Proof of the Implications: IFR→IFRA, IFR → DMRL, IFRA → NBU, NBU → NBUE, DMRL → NBUE, DFR → DFRA, DFR → IMRL, DFRA → NWU, NWU→ NWUE, IMRL → NWUE. 1.4 Examples	**12**

2	**Some parametric families of life distribution** **2.1** Classification of following parametric families of life distribution according to aging**:** Weibull, Gamma, lognormal, linear failure rate, Makeham, Pareto, Lehman. Distribution of specific parallel and series system. **2.2** Some Properties of Exponential Distribution: i) If $T_1, T_2, \ldots\ldots, T_n$ are independent with $T_i \rightarrow$ EXP (λ_i) for $i = 1,2,\ldots\ldots, n$ and $T = \min\{T_1, T_2, \ldots\ldots, T_n\}$ then $T \rightarrow EXP(\sum_{i=1}^{n} \lambda_i)$ ii) If $T_1, T_2, \ldots\ldots, T_n$ are independent and identically distributed exponential random variable with parameter λ, then $2\lambda(\sum_{i=1}^{n} \lambda_i) \rightarrow \chi^2_{2n}$ iii) If T is a continuous non-negative random variable with cumulative hazard rate R(t) then R(t) is exponential random variable with parameter 1. iv) If T follows the Weibull distribution with parameter λ and γ then T^{γ} has exponential distribution with parameter λ.	**10**
3	**Censoring and Nonparametric estimation of survival function** 3.1 Concept of censoring, order censoring, time censoring, right random censoring, left random censoring, undersigned censoring.Examples of lifetime situations. 3.2 Nonparametric estimation of survival function, confidence band on survival function, actuarial estimator of survival function, Greenwood's formula, Kaplan Meier estimator of survival function in the presence of censored observations.	**8**

Learning Resources- References

Sr. No.	References
1.	Barlow, R. E. and Proschan F. (1975) : Statistical theory of Reliability and Life testing: Probability Models Holt, Rinehart and Winston Inc.
2.	Barlow, R. E. and Proschan F. (1996) : Mathematical Theory of Reliability. John Wiley
3.	Cox, D.R. and Oakes, D. (1984) : Analysis of Survival Data, Chapman and Hall
4.	Deshpande, J.V. and Purohit S.G. (2005) : Life Time Data: Statistical Models and Methods, Word Scientific.
5.	Tobias, P.A. and Trindane, D. C. (1995) : Applied Reliability. Second edition. CRC Press
6.	J.Gertsbakh (2005) : Reliability theory with applications to preventive maintenance, springer
7.	Jerald F. Lawless (2002): Statistical methods and methods for lifetime data 2nd edition. Wiley
8.	William Q. *Meeker* and Luis A. Escobar (1998) : Statistic methods for reliability data, John Wiley & Sons.

	STS-355-Operations Management **Elective – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Discuss the concepts of inventory models , replacement models	1
CO2	Understand decision trees , uncertainty in decision making	2
CO3	Apply different criteria in decision making	3
CO4	Analyse the replacement models , queueing models	4
CO5	Compare different inventory models	5
CO6	Construct decision trees.	6

STS-355-Operations Management
(Elective – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Introduction to Operation Management** 1.1 Inventory Models: Always Better Control (ABC) analysis; Vital, Essential and Desirable (VED) Analysis. Fast moving, Non moving, Slow moving, Dead (FNSD) Analysis. Description of generalized inventory model. 1.2 Types of inventory models: a) The economic lot size model with uniform demand, instantaneous replenishment rate and no shortage (with derivation) b) The Economic lot size model with uniform rate of demand, finite replenishment rate and no shortage(with derivation) c) The economic lot size model with uniform demand, instantaneous replenishment with shortage(without derivation) d) The economic lot size model with uniform rate of demand, finite replenishment rate with shortage (without derivation).	**[10]**
2	**Decision Theory:** 2.1 Decision under risk: Expected value criteria 2.2 Decision Trees 2.3 Decision under uncertainty (a) Laplace criterion (b) Minimax / Maximax criterion (c) Savage minimax regret criterion (d) Hurwitz criterion	**[09]**

3	**Replacement Models** 3.1 Introduction 3.2 Replacement of item that deteriorates with time when (a) value of money remains same during the period (for time as a discrete variable and (continuous variable). (b)) value of money changes with constant rate during the period.	**[06]**
4	**Queueing Models** 4.1 Concept of queue as sequence of r.v.s., probability distribution of customers arriving in queue , interarrival time distribution, service time distribution, M/M/1 queue. 4.2 Performance measures in queueing theory. Applications.	**[05]**

Learning Resources- References

Sr. No.	References
1.	Gass E.: Linear Programming Method and Applications, Narosa Publishing House, New Delhi.
2.	Taha, R. A.: Operation Research – An Introduction, Fifth Edition, Prentice Hall of India, New Delhi.
3.	Saceini Yaspan, Friedman: Operation Research Method and Problems, Wiley International Edition.
4.	Shrinath L.S.: Linear Programming, Affiliated East-West Press Pvt. Ltd. New Delhi.
5.	Phillips, D.T., Ravindra, A., Solberg, J. : Operations Research Principles and Practice, John Wiley and Sons Inc.
6.	Sharma J. K.: Mathematical Models in Operations Research, Tata McGraw Hill Publishing Company Ltd., New Delhi.
7.	Kapoor, V. K.: Operation Research, Sultan Chand and Sons, New Delhi.
8.	Gupta, P. K. and Hira, D.S.: Operations Research, S. Chand and company Ltd., New Delhi.

	STS-356- Elements of Statistical Computing and Data Mining **Elective – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the concept of random numbers and interrelation among probability distributions	1
CO2	Understand the procedures of random number generation and describe the concept of classification. Explain the concept of bootstrap and EM algorithm	2
CO3	Demonstrate different random sample generation procedures from probability distributions and apply binary classifier in real life situations.	3
CO4	Compare the random number generation procedures on the basis of entropy.	4
CO5	Estimate sensitivity, specificity and accuracy of a classifier	5
CO6	Create confusion matrix and ROC curve	6

STS-356-Elements of Statistical Computing and Data Mining

(Elective – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Random number generators:** 1.1 Concept of randomness of sample, practical difficulties in generating randomness mid square algorithm and its limitations, requisites of good random number generator. 1.2 test for randomness: Run test, Poker's test, Concept of entropy as measure of randomness Significance of Kendall's τ / spearman's rank correlation empirical test viz. Kolmogorov Smirnov test 1.3 Specific random number generators : Linear Congruential Generator(L.C.G.), Mixed L.C.G., Multiplicative generator.	**[08]**
2	**Generating random variates:** 2.1 Methods to generate random variates. (a) Inverse transformation method. (b) Method of composition (c) Method of convolution (d) Acceptance Rejection method 2.2 Generating discrete random variates. (Using recurrence relation and inverse transformation method) Generating samples from (a) Bernoulli distribution (b) Binomial distribution (Also using composition method.) (c) Poisson distribution. (d) Geometric distribution (also using relation with exponential distribution.)	**[07]**

	2.3 Generating continuous random variates. Generating samples from (a) Uniform distribution using inverse transformation (b) Exponential distribution (c) Normal distribution using (i) Box muller method. (ii) Atkinson pearce method. (iii) Acceptance rejection method. (i)using Laplace distribution as majorising function (ii)using exponential distribution as majorising function (iii)using Cauchy as distribution majorising function	
3	**Applications of random number generation and random variate generations:** 3.1 Monte carlo integration (a) Computation of definite integral, Error in computation. (confidence interval for the value of integral) (b) Computation of some special integrals (i) empirical MGF (ii) empirical Laplace transform (iii) Estimating moments.	**[07]**
4	**Introduction to Bootstrapping and EM-Algorithm** 4.1 Concept of bootstrap, Bootstrapping in regression analysis, Bootstrap confidence, Bootstrap point estimation, EM-Algorithm	**[04]**
5	**Introduction to data mining** 5.1 Concept of database. 5.2 Extraction of data from database wrt research objective. 5.3 Concept of receiving operating characteristics (ROC) of algorithm / method. 5.4 Concept of specificity, sensitivity, accuracy. 5.5 Mathew's correlation coefficient, applications of ROC to association of some simple statistical procedures.	**[04]**

Learning Resources- References

Sr. No.	References
1.	Averill M. Law (2000): Simulation Modelling and Analysis, M.C. Graw Hill
2.	Debasis Kundu, Ayanendranath Basu (2004) : Statistical Computing, Narosa Publishing House
3.	Do Le Minh (2001) : Applied Probability Models, Duxbury.

	STS-357-Demography and Official Statistics **Elective – Theory**	
	Number of Credits: 02 **No. of Hours:30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the basic concepts of measures of demography.	1
CO2	Understand the concepts of Indian official statistics, mortality, fertility and reproduction rates, their computation and interpretation.	2
CO3	Apply methods of Official statistics in the field of Agriculture.	3
CO4	Compare different demographic ratios.	4
CO5	Estimate national income using different methods. Compute intercensal estimates using standard methods.	5
CO6	Construct life tables	6

STS-357-Demography and Official Statistics
(Elective – Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Demography:** **1.1 Measures of mortality**: Crude death rate, specific death rates-age, sex, occupation, standardized death rates (based on age specific death rates) direct and indirect methods, comparative study of these measures, numerical problems on these measures, infant mortality rate, neo-neonatal mortality rate, maternal mortality rate, old age mortality rate. **1.2 Measures of fertility**: Crude birth rate, general fertility rate, age specific fertility rate, total fertility rate, comparative study of these measures, numerical problems on these measures. **1.3 Reproduction rates**: GRR, NRR, comparison, interpretation, numerical problems. **1.4** Population Projection: Component method (description only), mathematical method – derivation of logistic law of population growth, interpretation of constants in the equation of the logistic curve.	**[3]**
2	**Life Tables:** **2.1** Construction and uses of a life table. Numerical problems.	**[2]**
3	**Census:** **3.1** General principles of census, utility of census methods, de-facto and de-jure methods, Indian Census 2011 : Houselist, establishment schedule, individual slip, population record, findings of 2011 census, estimation of intercensal estimates using standard methods.	**[06]**
4	**Indian Official Statistics:** **4.1 Agricultural Statistics** in India (i) Statistics of land utilization (ii) Statistics of crop output (iii) Miscellaneous of crop output (not to be studied in detail)	**[15]**

	(iv) Indices of agricultural production. Defects of Indian agricultural statistics. **4.2 Price statistics**: usefulness of price statistics, wholesale price statistics, index number of wholesale prices. Retail price statistics-labour bureau index, number of retail prices for urban and rural areas, consumer price index for industrial workers, non-manual employees and agricultural labourers, limitations of price statistics. **4.3 Industrial Statistics**: primary sources of industrial statistics, statistics collected (description in brief), limitations of industrial statistics, index number of industrial production. Method of compilation. Index number of industrial profits revised series. **4.4 Educational Statistics**: Description of different statistics relating to education, compiled and published by the ministry of education of the India Govt. Number of educational institutions, education of scheduled castes, tribes and backwards classes. Number of scholars, number of teachers, examination result. Sources of publications, critical study of educational statistics in India.	
5	**National Income:** **5.1** Definition (three approaches: product, income and expenditure). Methods of estimating national income: product method, income method, expenditure method and social accounting method.	**[04]**

Learning Resources- References

Sr. No.	References
1.	Spiegelaman M. (1955) Introduction to Demography, Society of Actuaries.
2.	Wolfendon H. H. (1954) Population Statistics and their compilation, Society of Actuaries.
3.	Goon Gupta and Dasgupta (1968) Fundamental of Statistics Vol. II., World Press.
4.	Asthana B. N. and Srivastava S. S. (1969) Applied Statistics of India. Chaitanya Publishing House, Allahabad.
5.	Gupta, S.C and Kapoor, V.K. (2008): Fundamentals of Applied Statistics, Sultan Chand & Sons Pvt. Ltd. New Delhi.
6.	RamKumar, R. (1986): Technical Demography, Wiley Eastern Limited.
7.	Pathak, K.B. and Ram, F. (1992): Techniques of Demographic Analysis, Himalaya publishing House censusindia.gov.in and www.rchiips.org.
8.	Cox. P. (1959): Demography, Cambridge University Press.
9.	Shrivastava, O.S. (1995): Demography and Population Studies, Vikas Publishing society.

	STS-361-Statistics Practical-8 **Major – Practical**	
	Number of Credits: 02 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Introduce the concept parametric and non-parametric tests.	1
CO2	Demonstrate the various situations to compute probability of type-1 error, power of the test. Also demonstrate the MP tests and UMP tests.	2
CO3	Apply various parametric and non-parametric tests to real life data. Compute survival function for various distributions.	3
CO4	Examine the suitability of tests. Verify the underlying assumptions for applying the tests.	4
CO5	Justify ergodicity of Markov chain. Non-parametric estimation of survival function for censored data.	5
CO6	Construct one step transition probability matrix	6

STS-361-Statistics Practical-8
(Major – Practical)

Unit No.	Title of Unit and Contents	No. of hours
1	Testing of hypotheses (Probability of type I and II errors, power of a test etc).	**4**
2	Construction of the most powerful (MP) test.	**4**
3	Construction of uniformly most powerful (UMP) test, plotting of power function of a test.	**4**
4	Parametric analysis of survival function and hazard rate for different distributions.	**4**
5	Actuarial estimator of survival function (in the presence of censored observations)	**4**
6	Kaplan-Meier estimator of survival function (in the presence of censored observations)	**4**
7	SPRT for Bernoulli, Binomial, Poisson. (graphical representation also).	**4**
8	SPRT for normal, exponential distribution. (graphical representation also).	**4**
9	Realization of Stochastics processes	**4**
10	Stochastic Process-I	**4**
11	Stochastic Process-II	**4**
12	Stochastic Process-III	**4**
13,14,15	Case studies	**12**

Note: The practicals on experiment number 4 to 6 are according to the major elective paper.

Learning Resources- References

Sr. No.	References
1.	Gibbons J.D.(2010): Non parametric Statistical Inference, 5th edn.CRC Press Book.
2.	Hogg, R.V. and Craig, R.G. (1989): Introduction to Mathematical Statistics, fourth edition,.Collier Macmillan International Edition, Macmillan Publishing Co. Inc., New York.
3.	Kale, B.K. and Muralidharan, K. (2015): Parametric Inference:An Introduction. Narosa, New Delhi.
4.	Hoel , P. G., Port, S.C. and Stone, C.J. (1972) :Introduction to stochastic processes, Wiley Eastern.
5.	Medhi J. (2009): Stochastic processes, New age International.
6.	Ross, S. (1996): Stochastic processes, 2nd edn. John Wiley.
7.	Hoel , P. G., Port, S.C. and Stone, C.J. (1972) :Introduction to stochastic processes, Wiley Eastern.
8.	Medhi J. (2009): Stochastic processes, New age International.
9.	Ross, S. (2014): Introduction to probability models, 11th edn, Elsevier.
10.	Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012). Introduction to Linear Regression Analysis Wiley. Fifth Edition
11.	Hosmer, D. W. and Lemeshow, S. (2013). Applied Logistic Regression, Wiley. Third Edition
12.	Chatterjee S. and Hadi A.S. (2012): Regression Analysis by Example, 5th Edition,Wiley.

	STS-362-Statistics Practical-9 **Major – Practical**	
	Number of Credits: 04 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Define bivariate and multivariate distributions.	1
CO2	Demonstrate the significance of the distributions and identify the real-life situations for bivariate and multivariate distributions. Explain the concept of bootstrap and EM algorithm	2
CO3	Demonstrate different random sample generation procedures from probability distributions and apply binary classifiers in real life situations.	3
CO4	Develop problem-solving techniques needed to accurately calculate probabilities.	4
CO5	Apply discriminant analysis techniques for solving real-world events. Evaluate bivariate normality.	5
CO6	Construct clusters for data generated in day to day life using cluster analysis.	6

STS-362-Statistics Practical-9
(Major – Practical)

Unit No.	Title of Unit and Contents	No. of hours
1	Applications of bivariate normal distribution	**4**
2	Model Sampling from bivariate normal distribution and evaluating bivariate normality.	**4**
3	Discriminant Analysis	**4**
4	Hierarchical Clustering Methods	**4**
5	Principal Component Analysis	**4**
6	K-Means Clustering Methods	**4**
7	Testing randomness by using (i) Run test (ii) Poker test	**4**
8	Generating random samples from discrete distribution	**4**
9	(i) Generating random samples from continuous distribution	**4**
10	Generating random samples from normal distribution using (ii) Box muller transformation (iii)At Kinston Pearce method	**4**
11	Computation of indefinite integral using Monte Carlo simulation.	**4**
12	Use of Bootstrap technique. Parameter estimation using EM algorithm	**4**
13,14&15	Case Studies	**12**

Note: The practicals on experiment number 6 to 12 are according to the major elective paper.

Learning Resources- References

Sr. No.	References
1.	Anderson, T. W. (2003), Introduction to Multivariate Analysis, 3rd edition, John Wiley
2.	Morrison, D.F. (1990), Multivariate Statistical Methods, McGraw Hill Co.
3.	Rao, C. R. (2002). Linear Statistical Inference and its Applications, Paperback edition Wiley Eastern
4.	Timm, N. H. (2002), Applied Multivariate Analysis, Springer, New York
5.	Johnson R.A. & Wichern, D.W. (2007). Applied Multivaria Statistical Analysis, Sixth Edition, Prentice Hall Inc.
6.	Averill M. Law (2000): Simulation Modelling and Analysis, M.C. Graw Hill
7.	Debasis Kundu, Ayanendranath Basu (2004) : Statistical Computing, Narosa Publishing House
8.	Do Le Minh (2001) : Applied Probability Models, Duxbury.

	STS-382-Statistics Practical-10 **VSC – Practical**	
	Number of Credits: 02 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall algorithms and programming. Define different terminology of C programming.	1
CO2	Articulate different situations where programming is helpful for analyzing the statistical data.	2
CO3	Apply the method to write simple C programs and use them to analyse the statistical data.	3
CO4	Examine the debugging of the programs as and when required to run the program successfully.	4
CO5	Consider and justify the use of Regression Analysis	5
CO6	Write simple programs in R and C for statistical data analysis.	6

STS-382-Statistics Practical-10
(VSC – Practical)

Unit No.	Title of Unit and Contents	No. of hours
1	Writing algorithms and drawing flowcharts for the given problems.	**4**
2	Writing program in C to carry out arithmetic calculations, to check whether given number is odd or even, to check whether a given number m is divisible by n or not, to find maximum of 2 numbers or 3 numbers.	**4**
3	Writing programs in C to find area of triangle and circle, to find roots of quadratic equation, to check whether integer is prime or not, to find sum of digits of a number.	**4**
4	Writing program in C to solve simultaneous linear equations. (two equations in two variables), to evaluate simple and compound interest, to prepare a multiplication table, to test palindrome string using string function, to sort a string using string function.	**4**
5	Writing program in C to prepare a discrete frequency distribution with given class interval from raw data and to find mean, variance, coefficient of variation of n numbers and to obtain correlation coefficient for given bivariate data and fit line of regression	**4**
6	Writing a program in C to obtain correlation coefficient for given bivariate data and fit line of regression, to arrange the observations in ascending order of magnitude and find median.	**4**
7	Regression analysis using R –I	**4**
8	Regression analysis using R –II	**4**

9	Design of experiments using R –I	**4**
10	Design of experiments using R –II	**4**
11	Study of characteristics and computation of probability of events related to probability distributions 1) Log normal 2) Laplace 3) Cauchy and 4) Weibull distribution using R	**4**
12	Statistical inference using R : (i) To obtain confidence interval of median using order statistics (ii) To obtain MLE of location parameter μ of Cauchy distribution (iii) To study asymptotic behaviour of an estimator using R software.	**4**
13,14&15	Case studies	**12**

Learning Resources- References

Sr. No.	References
1.	Yashwant Kanetkar (2022) - Let us C : Authentic guide to C programming language, BPB publications
2.	E Balagurusamy (2017) - Computing fundamentals and C programming McGraw Hill publication
3.	E Balagurusamy (2013) - Data structures using C, McGraw Hill publication
5.	Crawley, M. J. (2006) Statistics - An introduction using R.John Wiley, London 32
6.	Verzani, J. (2005). Using R for Introductory Statistics, Chapman and Hall / CRC Press, New York
7.	Purohit, S. G., Gore S. D., Deshmukh S. R. (2008). Statistics Using R, Narosa PublishingHouse, New Delhi. Eighth Ed. East - West Press. Statistics, Vol. 1,

	STS-371-Statistical Techniques-III **Minor -Theory**	
	Number of Credits: 02 **No. of Hours: 30**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall the concepts of data. Define index numbers, Discuss components of time series	1
CO2	Illustrate the use of index numbers Understand the concept of trend and seasonality in a time series.	2
CO3	Apply different method to compute consumer price index number	3
CO4	Analyse the data using commands of R software	4
CO5	Determine measures of central tendency and dispersion of different data sets using R,Compare index numbers	5
CO6	Construct different diagrams and graphs using commands of R software for data presentation.	6

STS-371-Statistical Techniques-III
(Minor –Theory)

Unit No.	Title of Unit and Contents	No. of hours
1	**Fundamentals of R:** 1.1 Overview of the R language, Input and output of data in R, Help command, In-built functions in R, installing packages and libraries, 1.2 Creating a vector using scan function, creating a data frame using edit command, Importing data from MS-Excel file Using read.table command, saving the R-output in a file using MS-Excel, concept of R-script file, Graphics using R: (a) High level plotting functions (b) Low level plotting functions (c) Interactive graphic functions 1.3 Diagrams: Simple bar diagram, Subdivided bar diagram, multiple bar diagram, Pie diagram, Stem and leaf diagram 1.4 Graphs Boxplot for one and more than one variables, rod or spike plot, histogram for raw data for both equal and unequal class intervals, frequency polygon, ogive curves, saving the diagram and graph in MS-Word file **Summary Statistics using R**: 1.5 Measures of Central Tendency: Computation of the following for ungrouped and grouped data: Arithmetic Mean (A.M.) Mode and Median 1.6 Measures of Dispersion Computation of the following for ungrouped and grouped data: Range, Variance and standard deviation, coefficient of variation (C.V.).	**[10]**

2	**Index Numbers** 2.1 Introduction of index numbers, Definition and meaning, 2.2 Problems/considerations in the construction of index Numbers, 2.3 Simple and weighted price index numbers based on price relatives, Simple and weighted index numbers based on aggregates, 2.4 Laspeyre's, Paasche's and Fisher's Index numbers. 2.5 Time reversal Test, factor reversal test, circular test, 2.6 Consumer price index number: Methods of construction of consumer price index number: (i) Family budget method (ii) Aggregate expenditure method. 2.7 Shifting of base, splicing, deflating and purchasing power. 2.8 Description of the BSE sensitivity and similar index numbers.	**[10]**
3	**Time Series Analysis**: 3.1 Meaning of Time Series, Various components of a time series (Explanation and illustrations of each component). Additive and Multiplicative methods for analysis of time series. 3.2 Methods of estimating trend: (i) Freehand or Graphical method (ii) Method of semi-averages (iii) Method of moving averages (iv) Method of least squares 3.3 Methods of estimating seasonal components (i) Methods of averages (ii) Ratio to trend obtained by moving averages (iii) Link Relative Method 3.4 Decomposition of Time series 3.5 Single Exponential smoothing	**[10]**

Learning Resources- References

Sr. No.	References
1.	Gupta,S. C. and Kapoor V.K.(2007), Fundamentals of Applied Statistics(Fourth Edition), Sultan Chand and Sons, New Delhi.
2.	Gupta, S. P. (2002), Statistical Methods (31st Edition), Sultan Chand and Sons, 23, Daryaganj, New Delhi 110002.
3.	Mood, A. M., Graybill F. A. and Bose, F. A. (1974), Introduction to Theory of Statistics (Third Edition, Chapters II, IV, V, VI), McGraw - Hill Series G A 276
4.	Mukhopadhya Parimal (1999), Applied Statistics, New Central Book Agency, Pvt. Ltd. Kolkata
5.	Weiss N., Introductory Statistics, Pearson education publishers
6.	Crawley, M. J. (2006) Statistics - An introduction using R.John Wiley, London 32
7.	Verzani, J. (2005). Using R for Introductory Statistics, Chapman and Hall / CRC Press, New York
8.	Purohit, S. G., Gore S. D., Deshmukh S. R. (2008). Statistics Using R, Narosa PublishingHouse, New Delhi. Eighth Ed. East - West Press. Statistics, Vol. 1,
9.	Montgomery, D.C. and Johnson L.A. (1976): Forecasting and Time Series Analysis, McGraw Hill.
10.	Farmum, N.R. and Stantorr, L.W. (1989): Quantitative Forecasting Methods, PWSKent Publishing Company, Boston.
11.	Christopher Chatfield (1975): The Analysis of Time Series, 6th edition,CRC Press.

	STS-395-On Job Training **OJT -Theory/Practical**	
	Number of Credits: 04 **No. of Hours: 180**	

STS-395-On Job Training
(OJT -Theory/Practical)

Unit No.	Title of Unit and Contents	No. of hours
	The detail content for this course is available on college website	

	STS-374-Sampling Methods and its Applications **Minor – Theory (B.A.)**	
	Number of Credits: 04 **No. of Hours: 60**	
Course Outcomes (COs) **On completion of the course, the students will be able to:**		**Bloom's cognitive level**
CO1	Recall concepts of sample, population and various types of simple random sampling methods	1
CO2	Explain the need of stratification and making clusters and allocation problems in stratified random sampling.	2
CO3	Choose a sample of suitable size by using various sampling methods to collect data in day today life and Calculate estimates of unbiased estimators and their standard errors in various sampling methods.	3
CO4	Distinguish between cluster random sampling and stratified random sampling	4
CO5	Compare simple random sampling, stratified random sampling and systematic sampling and classify sampling and non-sampling errors	5
CO6	Design questionnaires and plan sample surveys to collect data.	6

STS-374-Sampling Methods and its Applications
(Minor – Theory) (B.A.)

Unit No.	Title of Unit and Contents	No. of hours
1	**Sampling:** 1.1 Concept of distinguishable elementary units, sampling units, sampling frame, random sample, requisites of a good sample. Simple random sampling from finite population of size N (i) with replacement (SRSWR) ii) without replacement (SRSWOR) definitions. 1.2 Population mean and population total as parameters, inclusion probabilities. (a) Sample mean $\bar{y}$ as an estimator of population mean, expression for expectation and standard error of $\bar{y}$, confidence interval for population mean, population total. (b) N $\bar{y}$ as an estimator of population total, expression for expectation and standard error of N $\bar{y}$. (c)Estimator of above standard errors, both in case of SRSWR and SRSWOR. 1.3 Sampling for proportion as an application of a simple random sampling with X_i as zero or one. (a) sample proportion as an estimator of population proportion of units possessing a certain attribute, expression for expectation and standard error of estimator (p).	**[14]**

	(b) Np as an estimator of total number of units in the population possessing a certain attribute, expression for expectation and standard error of estimator Np (c) Estimator of above standard error both in case of SRSWR and SRSWOR.	
2	**Determination of Sample Size:** 2.1 Determination of the sample size for the given: i) Margin of error and confidence coefficient. ii) Coefficient of variation of the estimator and confidence coefficient.	**[7]**
3	**Stratified Random Sample Size:** 3.1 Stratification, basis of stratification, real life situation where stratification can be used. Stratified random sampling as a sample drawn from individual strata using SRSWOR in each stratum. (a) $\overline{y_{st}} = \frac{\sum N_i \overline{y_i}}{N}$ as an estimator of population mean ($\overline{Y}$) expression for expectation and standard error of $\overline{y}_{st}$. (b) N $\overline{y}_{st}$. as an estimator of population total, expression for expectation and standard error of N $\overline{y}_{st}$. (c) Estimator of above standard errors.Problem of allocation, proportional allocation, Neyman's allocation, the expressions for the standard errors of the above estimators when these allocations are used. Gain in precision due to stratification, comparison amongst SRSWOR, stratification with proportional allocation and stratification with Neyman's allocation.	**[14]**
4	**Ratio and Regression Methods of Estimation for SRSWOR:** 4.1 Rationale behind using auxiliary variates in estimation situations where (i) ratio method is appropriate, (ii) regression method is appropriate 4.2 Ratio and regression estimators of the population mean and population total	**[10]**
5	**Systematic Sampling (Population size divisible by sample size):** 5.1 Real life situations where systematic sampling is appropriate. Techniques of drawing a sample using systematic sampling. 5.2 Estimation of the population mean and population total, standard error of these estimators.	**[05]**
6	**Role of Sample Surveys in Research Methodology:** 6.1 Objectives of a sample survey 6.2 Designing a questionnaire, characteristics of a good questionnaire (Questions with codes & scores are to be discussed). 6.3 Reliability and validity testing by using (i) Test – Retest method (ii) Internal Consistency: (A) Kuder Rechardson Coefficient (KR-20) (B) Cronbach's Coefficient Alpha 6.4 Planning, execution and analysis of a sample survey, practical problems at	**[10]**

	each of these stages 6.5 Sampling and non-sampling errors with illustrations 6.6 Study of some surveys illustrating the above ideas, rounds conducted by National Sample Surveys organization	

Learning Resources- References

Sr. No.	References
1.	Cochran, W.G. (1977) Sampling Techniques, third Edition Wiley Eastern Ltd., New Delhi.
2.	Malhotra N. (2008). Marketing Research and Applied Orientation (third edition), Prentice Hall of India. New Delhi.
3.	Mukhopadhyay P (2008). Sampling theory and methods of Survey sampling. Prentice-Hall of India, New Delhi.
4.	Murthy, M. N. (1967). Sampling methods, Indian Statistical Institute, Kolkata.
5.	Singh, D. and Chaudhary, F. S. (1986). Theory and 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.