K. J. Somaiya College of Science and Commerce

Autonomous- Affiliated to University of Mumbai

(Re-accredited "A" Grade by NAAC)

Department of Statistics

T. Y. B. Sc.

Proposed Syllabus

(With effect from 2023-24)

Semester – V (Theory)

Course	Course Name	Course code
I	Probability Theory	23US5STCC1PRT
II	Probability Distribution-II	23US5STCC2PRD2
III	Theory of Estimation	23US5STCC3TOE
IV	Regression Analysis	23US5STCC4REG
V – DSE-1	Demography and Vital Statistics	23US5STDS1DVS
	Econometrics	23US5STDS1ECO
VI – DSE-2	Operation research-II	23US5STDS2OPR2
	Linear Models	23US5STDS2LIM
VII – Skill Enhancement course	SQL and R-Programming	23US5STSECSQR

Semester – V (Practical)

Course	Course Name	Course code
I	Theory Course I + Theory course II	23US5STCCP1
II	Theory Course III + Theory course IV	23US5STCCP2
III	DSE-1 + DSE-2	23US5STDSP3

Semester – VI (Theory)

Course	Course Name	Course code
I	Reliability & Survival Analysis	23US6STCC1RSA
II	Testing of hypothesis	23US6STCC2TOH
III	Stochastic Processes	23US6STCC3STP
IV	Elements of actuarial science	23US6STCC4EAS
V – DSE-1	Data Mining and Statistical Learning	23US6STDS1DMS
	Biostatistics	23US6STDS1BST
VI – DSE-2	Time series analysis	23US6STDS2TSA
	Design of Experiments-II	23US6STDS2DOE2
VII – Skill Enhancement course	Python programming	23US6STSECPYP

Semester – VI (Practical)

Course	Course Name	Course code
I	Theory Course I + Theory course II	23US6STCCP1
II	Theory Course III + Theory course IV	23US6STCCP2
III	DSE-1 + DSE-2	23US6STDSEP3

Course Title: Probability Theory **Core Course: I (Semester-V)**

Course Code: 23US5STCC1PRT **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Compute probability of events by using laws of probability. 2) Understand Probability Inequalities and WLLN. 3) Obtain Probability distribution of order statistics and functions of it.
Course Outcomes:	**By the end of this course, learner will able to** 1) Compute probabilities of events. 2) Apply Bayes' theorem to real life problems 3) Apply probability inequalities. 4) Derive probability distribution of order statistics, sample range and sample median.

Module – 1	**Probability**	**14 Lect**
	Learning Objectives: The module is intended 1) Explain basic concepts in probability. 2) Calculate the probability that an event will occur. 3) Understand four approaches to obtain probability. 4) Compute the probability of complex events. 5) Solve applications involving probabilities.	
	Learning Outcomes: By the end of this module, learner will able to 1) Compute probabilities of events using different theorems of probability. 2) Apply Bayes' theorem and laws of probability to real life problems.	
a)	**Sample Space, Sample point, Event:** Impossible event, Sure event, Complementary event, Union and intersection of 'n' events,	

	Mutually exclusive and Exhaustive events, pair-wise independent events	
b)	Mathematical, Statistical, Axiomatic probability.	
c)	**Theorems on Probability of realization of :** (i) At least one; (ii) Exactly m; (iii) At least m, of N events A_1, A_2, A_3…A_N. Classical occupancy problems, Matching and Guessing problems. Problems based on them.	
d)	**Conditional Probability:** Multiplication Theorem for two, three events. Independence of two/three events - complete and pair wise, Generalization to n events. Bayes' theorem and its applications	

Module – 2	**Inequalities and Law of Large Numbers**	**10 Lect**
	Learning Objectives: The module is intended to 1) Understand the various probability inequalities 2) Understand Weak Law of Large Numbers	
	Learning Outcomes: By the end of this module, learner will able to 1) Apply different probability inequalities and WLLN.	
a)	Markov's Inequality	
b)	Chebyshev's Inequality	
c)	Boole's Inequality	
d)	Cauchy Schwarz Inequality	
e)	Jensen's Inequality	
f)	Weak law of large numbers.	

Module – 3	**Order Statistics**	**12 Lect**
	Learning Objectives: The module is intended 1) To explain meaning and importance of order statistics 2) To derive distribution of order statistics	

	3) To use order statistics in finding distribution of sample range	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand meaning and scope of order statistics. 2) Determine the pdf of single and joint order statistics. 3) Obtain pdf of sample range.	
a)	Definition of Order Statistics based on a random sample.	
b)	Derivation of: i) Cumulative distributions function of r^{th} order statistic. ii) Probability density functions of the r^{th} order statistic. iii) Joint Probability density function of the r^{th} and the s^{th} order statistic (r<s) iv) Joint Probability density function of all n ordered statistics. v) Probability density function of Median (in the case of odd sample sizes) and Range for Uniform and Exponential distributions.	

References:

1. Feller W (2014) : An introduction to probability theory and it's applications, Volume:1, Third edition,Wiley Eastern Limited.
2. Hogg R. & Craig A. (1995): Introduction to Mathematical Statistics, Fifth edition, Pearson Education (singapore) Pvt Ltd.
3. Mood A., Graybill, Boes D. (1974): Introduction to the theory of statistics, Third edition, Mcgraw-Hill Series
4. Hogg R. V. and Tanis E.A.(2006) : Probability and Statistical Inference, Fourth edition, McMillan Publishing Company
5. Gupta S C & Kapoor V K (2011): Fundamentals of Mathematical statistics, Eleventh edition, Sultan Chand & Sons.
6. Biswas S. (1992): Topics in Statistical Methodology, First edition, Wiley Eastern Ltd.
7. Kapur J. N., Saxena H. C. (1963): Mathematical Statistics, Fifteenth edition, S. Chand and Company.
8. Ross Sheldon (2001): A first course in probability (6^{th} edition): Pearson Edu., Delhi
9. Rohatgi V.K. (2017): An introduction to probability theory and Statistics.

Course Title: Probability Distributions **Core Course: II (Semester-V)**

Course Code: 23US5STCC2PRD2 **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Fit various continuous probability distributions and to study various real life situations. 2) Identify the appropriate probability model that can be used.
Course Outcomes:	**By the end of this course, learner will able to** 1) To apply the various continuous distributions for analyzing the data. 2) To estimate the probability of different events in cases where there are more than 2 outcomes. 3) To apply normal distribution for 2 variables.

Module – 1	**Probability Distributions**	**18 Lect**
	Learning Objectives: The module is intended to 1) Understand the nature of probability distributions.	
	Learning Outcomes: By the end of this module, learner will able to 1) Apply the various continuous distributions for analyzing the data.	
a)	**Weibull distribution** $f(x) = \frac{\beta}{\alpha}\left(\frac{x-\gamma}{\alpha}\right)^{\beta-1} exp\left\{\left(\frac{x-\gamma}{\alpha}\right)^{\beta}\right\} \quad x \geq \gamma, \quad \alpha, \beta > 0$ $= 0 \quad otherwise$ i) pdf , Notation : X ~ W (γ, α, β). ii)Distribution function, quartiles. iii) r^{th} Moment about x = γ , mean and variance. iv) Relation with exponential distribution. v) Examples and problems	

b)	**Laplace distribution** $f(x) = \frac{\lambda}{2} exp\{-\lambda\|x-\mu\|\};\ -\infty < x < \infty, -\infty < \mu < \infty, \lambda > 0$ $= 0 \quad ; otherwise$ i) pdf, Notation : X ~ L (μ, λ) ii) Nature of probability curve. iii) Distribution function, quartiles. iv) mgf, cgf, moments and cumulants, β_1, β_2, γ_1, γ_2. v) Laplace distribution as the distribution of the difference of two i.i.d exponential variates with mean θ. vi) Examples and problems	
c)	**Lognormal distribution** $f(x) = \frac{1}{(x-a)\sigma\sqrt{2\pi}} exp\left\{-\frac{1}{2\sigma^2}[log_e(x-a)-\mu]^2\right\}$ $; x > a, -\infty < x < \infty, \sigma > 0$ i) pdf , Notation : X ~ LN (a, μ, σ^2) ii) Nature of the probability curve. iii) Moments (rth moment about x=a), first four moments, β1 and γ1, coefficients, quartiles. iv) Examples and problems.	
d)	**Cauchy distribution** $f(x) = \frac{\lambda}{\pi} \frac{1}{\lambda^2 + (x-\mu)^2} \ ; -\infty < x < \infty, -\infty < \mu < \infty, \lambda > 0$ i) pdf, Notation : X~ C(μ, λ) ii) Nature of probability curve. iii) Distribution function, quartiles, non-existence of moments. iv) Additive property for two independent Cauchy variates (Statement only), Statement of distribution of the sample mean. v) Relationship with uniform and Student's 't' distribution. vi) Examples and problems.	
e)	**Pareto distribution** i) $f(x) = \frac{\alpha k^\alpha}{x^{\alpha+1}} \quad ; k \le x < \infty, \quad \alpha, k > 0$	

	ii) Cumulative distribution function iii) Moment Generating Function	

Module – 2	**Joint MGF, Trinomial & Multinomial Distribution**	**6 Lect**
	Learning Objectives: The module is intended to 1) Understand extension of binomial distribution to Trinomial and Multinomial distribution. 2) Derive marginal and conditional distribution and other properties of Trinomial and Multinomial distribution.	
	Learning Outcomes: By the end of this module, learner will able to 1) Apply Trinomial and Multinomial distributions in real life problems. 2) Understand properties of these distributions.	
a)	**Bivariate Moment Generating Function** i) Definition ii) Marginal Moment Generating Function iii) E(X^r), E(Y^s) & E(X^r Y^s) iv) Joint Moment Generating Function v) Examples	
b)	**Trinomial distribution** i) Definition of joint probability distribution of (X, Y). ii) Joint moment generating function, moments μrs where r=0, 1, 2 and s=0, 1, 2. iii) Marginal & Conditional distributions. Their Means & Variances. Correlation coefficient between (X, Y). iv) Distribution of the Sum X+Y.	
c)	**Multinomial Distribution** i) Extension to Multinomial distribution with parameters (n, p_1 , p_2,…p_{k-1}) where p_1+ p_2,+…p_{k-1}+ p_k= 1. ii) Expression for joint MGF. Derivation of: joint probability distribution of (X_i, X_j).	

	iii) Conditional probability distribution of Xi given $X_j = x_j$	

Module – 3	**Bivariate Normal Distribution**	**12 Lect**
	Learning Objectives: The module is intended to 1) Demonstrate the univariate and bivariate normal distribution. 2) Apply Bivariate Normal Distribution in real life problems. 3) To derive test statistics for testing significance of population correlation coefficient.	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand the properties of Bivariate Normal Distribution. 2) Find moment generating function, marginal and conditional distributions in Bivariate Normal Distribution. 3) Apply Bivariate Normal Distribution in real life problems. 4) Test significance of population correlation coefficient.	
a)	i) Definition of joint probability distribution (X, Y). ii) Joint Moment Generating function, moments μ_{rs} where r=0, 1, 2 and s=0, 1, 2. iii) Marginal & Conditional distributions. Their Means & Variances. Correlation coefficient between the random variables.	
b)	Necessary and sufficient conditions for the independence of X and Y. Distribution of aX + bY, where 'a' and 'b' are constants.	
c)	Distribution of sample correlation coefficient when $\rho = 0$.	
d)	Testing the significance of a correlation coefficient.	
e)	Fisher's z – transformation.	
f)	Tests for i) H_0: $\rho = \rho_0$ ii) H_0: $\rho_1 = \rho_2$ Confidence interval for ρ.	

References:

1. Mood A. M, Graybill F. Bose D. C.(1974), Introduction to theory of Statistics (III Edn.) McGraw Hill Series.
2. Hogg R.V. and Graig A. T.(1970) : Introduction to Mathematical Statistics (3rdEdn.) , Macmillan Publishing Co. Inc. New York.

3. S.C. Gupta and V.K. Kapoor(2014) : Fundamentals of Mathematical Statistics, 12th Edition, Sultan Chand and Sons, 88 Daryaganj New Delhi 2.
4. Rohatgi V.K. (1975) An Introduction to probability Theory and Mathematical Statistics Wiley Eastern Ltd .New Delhi.
5. Mukhopadhyay, P (1996). Mathematical Statistics, New Central Book Agency.
6. Dasgupta A. (2010) Fundamentals of Probability: A first course, Springer, New York.

Course Title: Theory of Estimation **Core Course: III (Semester-V)**

Course Code: 23US5STCC3TOE **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Understand the properties of the best estimator. 2) Learn the different methods to obtain the estimators. 3) Estimate the parameter when the parameter itself is a r.v. 4) Obtain the confidence interval for the unknown parameter.
Course Outcomes:	**By the end of this course, learner will able to** 1) Apply the different properties and decide which estimator is the best estimator. 2) Estimate the unknown parameter using different methods of estimation. 3) Estimate the unknown parameter when the parameter itself is a r.v. 4) Obtain the confidence interval for a parameter for a given level of significance.

Module – 1	**Point Estimation and its Properties**	**16 Lect**
	Learning Objectives: The module is intended to 1) Study the properties of the estimator.	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand the concept of point and interval estimation. 2) Check unbiasedness and consistency properties of the estimator. 3) Obtain Cramer Rao Lower Bound for the estimator. 4) Calculate the efficiency of the estimator. 5) Obtain the sufficient estimator of the parameter.	
a)	**Definitions and Notations** Notion of a parameter and parameter space. General problem of estimation, Definitions of Statistic, Estimator and Estimate.	

	Concept of Point and Interval estimation.	
b)	**Properties of estimator** **i) Unbiasedness**: Definition of an unbiased estimator, biased estimator, positive and negative bias, examples (these should include unbiased and biased estimators for the same parameters). Proofs of the following results regarding unbiased estimators. Two distinct unbiased estimators of $\varphi(\theta)$ give rise to infinitely many unbiased estimators. If T is an unbiased estimator of θ , then $\varphi(T)$ is unbiased estimator of $\varphi(\theta)$ provided $\varphi(.)$ is a linear function. **ii) Sufficiency**: Definition of likelihood function as a function of the parameter θ for a random sample from discrete and continuous distributions. Concept and definition of Sufficiency, definition of sufficient statistic through (i) conditional distribution (ii) Fisher Neyman factorization criterion. Obtain sufficient statistic for standard distributions **iii) Efficiency, Fisher information function:** Amount of information contained in statistic $T = T(X_1, X_2, \ldots, X_n)$. Statement regarding information in a sample and in a sufficient statistic T. Cramer- Rao Inequality: Statement and proof, Cramer – Rao Lower Bound (CRLB), definition of minimum variance unbiased estimator (MVUE) of $\phi(\theta)$ Comparison of variance with CRLB, relative efficiency of T1 w.r.t. T2. Efficiency of unbiased estimator T w.r.t. CRLB. **iv) Consistency**: Definition. Proof of the following: An estimator is consistent if its bias and variance both tend to zero as the sample size tends to infinity. If T is consistent estimator of θ and $\varphi(.)$ is a continuous function then $\varphi(T)$ is consistent estimator of $\varphi(\theta)$	

Module – 2	**Methods of Estimation**	**10 Lect**
	Learning Objectives: The module is intended to 1) Estimate the parameters using different methods of estimation**.**	

	Learning Outcomes: By the end of this module, learner will able to 1) Estimate the parameter/s using the appropriate method of estimation.	
a)	**Method of Maximum Likelihood Estimation (M.L.E.):** Principle of M.L.E. Procedure to find M.L.E., Properties of M.L.E (without proof) Derivation of M.L.E. for parameters of standard distributions (case of one and two unknown parameters). M.L.E. of θ in uniform distribution over i) $(0, \theta)$ ii) $(-\theta, \theta)$ M.L.E. of θ in $f(x ; \theta)= \text{Exp}\{-(x- \theta)\}$, $x > \theta$.	
b)	**Method of Moments for one and two parameter family:** Definition, Derivation of moment estimators for standard distributions. Illustrations of situations where M.L.E. and Moment Estimators are distinct and their comparison.	
c)	**Method of Minimum Chi-square and Modified Minimum Chi-square:** Definition, Simple examples	

Module – 3	**Bayes Estimation and Interval Estimation**	**10 Lect**
	Learning Objectives: The module is intended to 1) Estimate the parameter when the parameter itself is a random variable. 2) Obtain the interval estimation for the parameter as per the level of significance mentioned.	
	Learning Outcomes: By the end of this module, learner will able to 1) Estimate the parameter when the parameter itself is a random variable. 2) Obtain the interval within which the parameter lies for small samples as well as for large samples..	
a)	**Bayesian Estimation:** Prior distribution, Posterior distribution, Loss function, Risk	

	function, Bayes solution under Squared Error Loss Function (SELF) and Absolute Error Loss function.	
b)	**Interval Estimation:** Concept of Confidence Interval and Confidence Limits. Derivation of 100(1-α) % equal tailed confidence interval i) for the parameters μ, $\mu_1 - \mu_2$ (Population variance(s) known / unknown), σ^2 , $\sigma_1{}^2/\sigma_2{}^2$ (Normal distribution). ii) based on the asymptotic property of M.L.E. iii) based on pivot	

References:

1. R.V.Hogg, A.T. Craig (1995): Introduction to Mathematical Statistics, Fifth Edition, Prentice Hall Of India/ Phi
2. R.V.Hogg, E. A.Tannis (2011): Probability and Statistical Inference, Pearson Education.
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4. John E. Freund's Mathematical Statistics (2001): Fifth Edition; Phi (Eastern Eco. Ed.).
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Course Title: Regression Analysis **Core Course: IV (Semester-V)**

Course Code: 23US5STCC4REG **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Understand and apply Simple, Multiple linear regression and logistic regression.
Course Outcomes:	**By the end of this course, learner will able to** 1) Fit the simple, multiple linear regression model. 2) Fit the Logistic Regression model. 3) Analyze various regression models. 4) Validate various assumptions.

Module –1	**Estimation of parameters of linear regression model**	**12Lect**
	Learning Objectives: The module is intended to 1) Explain basic concepts in linear regression. 2) Estimate the parameters involved in the regression model.	
	Learning Outcomes: By the end of this module, learner will able to 1) Fit the linear regression model.	
a)	**Simple Linear Regression Model:** Derivation of OLS estimators of the regression coefficients, Properties of least square estimators (with proof), Coefficient of determination, Estimation of σ^2 Assumptions of Classical Linear Regression Model	
b)	**Multiple Linear Regression Model:** Linear regression model with two explanatory variables Derivation of OLS estimators of the regression coefficients, Properties of least square estimators (with proof), Coefficient of determination and adjusted R^2, Estimation of σ^2	

Module – 2	Analysis of linear regression model	12 Lect
	Learning Objectives: The module is intended to 1) Understand the process of analysis of linear regression models.	
	Learning Outcomes: By the end of this module, learner will able to 1) Analyze linear regression model. 2) Obtain Confidence interval for regression parameters. 3) Select independent variables affecting the output. 4) Analyze residuals using different plots.	
a)	**Procedure of testing:** a) Overall significance of the regression model b) significance of individual regression coefficients c) confidence intervals for the regression coefficients of Simple and Multiple Linear regression model d) significance of incremental contribution of explanatory variables for two explanatory variables model	
b)	Detection and treatment of missing values and outliers	
c)	**Variable Selection and model building:** Forward Selection Method, Backward Elimination Method, Stepwise Regression Method	
d)	**Residual analysis:** Standardized residuals, residual plots, testing normality of residuals	

Module – 3	Validity of Assumptions of linear regression and Introduction to Logistic regression	12 Lect
	Learning Objectives: The module is intended to 1) Test various assumptions for the application of linear regression model. 2) Understand the concept of logistic regression.	
	Learning Outcomes: By the end of this module, learner will able to	

	1) Check the assumptions of linear regression models 2) Apply methods to estimate the parameters in presence of Heteroscedasticity and Autocorrelation. 3) Fit logistic regression.	
a)	**Autocorrelation:** Concept, Detection using Durbin-Watson test, Run test, GLS method	
b)	**Heteroscedasticity:** Concept, Detection using Spearman's rank correlation test, BPG test, WLS method	
c)	**Multicollinearity:** Concept, Detection using R^2 and t-ratios, pairwise correlation between regressors, VIF	
d)	**Introduction to Logistic regression:** Example, Model, Odds ratio, Logit transformation, Interpretation of parameters, Estimation of parameters	

References:

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

Discipline Specific Elective-1 (Sem-V)

Course Title: Demography and Vital Statistics **DSE-1 Course: V (Semester-V)**

Course Code: 23US5STDS1DVS **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Identify appropriate sources of data, perform basic demographic analyses using various techniques and ensure their comparability across populations. 2) Be able to produce population projections and interpret the information gathered by the different demographic methods. 3) Explain different parts of life table
Course Outcomes:	**By the end of this course, learner will able to** 1) Comprehend the basic concepts and definitions in Demography 2) Familiar with different concept of official statistics of India 3) Identify the various sources of data in Demography 4) Evaluate basic measures of fertility, mortality and migration 5) Understand construction of different columns of life tables

Module – 1	**Introduction to demography and sources of demographic data**	**12 Lect**
	Learning Objectives: The module is intended to 1) Introduce the basic concepts of demography and sources of demographic data 2) Explain functioning of different Indian statistical organizations	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand functioning of different Indian statistical organizations 2) Understand History of Population changes of world 3) Understand different sources of collecting demographic data	
a)	**Introduction to Demography:** Definition and Scope; Historical trends in population situation in the world; Present population	

	situation in India and in the world and in developed countries	
b)	**Introduction to Indian and International Statistical Systems:** Role, function and activities of central and state statistical organizations; Role of Registrar General of India (RGI) and National Sample Survey Organization (NSSO); General and special data dissemination systems	
c)	**Sources of Demographic Data:** Population census - uses and limitations; Various demographic (e.g., Nuptiality, Fertility, Mortality, and Migration) data sources and its quality - Vital registration System (VRS), National Sample Survey Organization (NSSO) Sample Registration System (SRS), Demographic Health Surveys (DHS) and other sources	

Module – 2	**Basic measures of fertility, mortality and migration**	**12 Lect**
	Learning Objectives: The module is intended to 1) Impart skills in the basic measures of fertility, mortality and migration	
	Learning Outcomes: By the end of this module, learner will able to 1) Evaluate basic measures of fertility, mortality and migration.	
a)	**Basic Concepts and Measures of Fertility:** Natality measures - Crude Birth Rate (CBR); Fertility measures - General Fertility Rate (GFR), General Marital Fertility Rate (GMFR), Age Specific Fertility Rate (ASFR) and Total Fertility Rate (TFR); Measures of reproduction - Gross Reproduction Rate (GRR) and Net Reproduction Rate (NRR)	
b)	**Basic Concepts and Measures of Mortality:** Calendar and cohort concept of rate, Crude Death Rate (CDR), Age Specific Death Rate (ASDR); Their relative merits and demerits; Techniques of direct and indirect standardization of death rates; Child and infant mortality rates - Neonatal Mortality Rate (NMR), Post Neonatal Mortality Rate (PNMR), Infant Mortality Rate	

	(IMR), Child Mortality Rate (CMR) and Under Five Mortality Rate (U5MR)	
c)	**Basic Concepts and Measures of Mobility and Migration:** Definition of migration including types of migration, census definition of migrants; Sources, quality and limitations of migration data; Direct and indirect (The Vital Statistics Method, The Survival Ratio Method, and Migration Rate) measurement methods of migration; Concept of international migration	

Module – 3	**Life table and population projection**	**12 Lect**
	Learning Objectives: The module is intended to 1) Acquire skills to use life tables and getting knowledge of different population projection methods	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand and construct different columns of life tables 2) Estimate and project the population of specific regions	
a)	**Basic Concepts and Construction of a life table:** Definition, use/importance, and types of life tables; Assumptions for preparing life tables; Description of abridged life tables; Interrelations among life table functions; Methods of construction of abridged life tables – Conventional method including Reed Merrell Method, Greville's Method and Chiang Method; Brief concept of model life tables – United Nations Model Life Tables, and Coale and Demeny's Regional Model Life Tables	
b)	**Basic Concepts and Methods of Population Projection:** Definition, types and use of population projection; Concept of population estimate, population forecast and population projection; Methods of interpolation and extrapolation using Linear, Exponential, Polynomial, Logistics, Gompertz curves and growth rate models	

References:

1. Guide to Official Statistics, CSO, 1999
2. Statistical System in India, CSO, 1995
3. Jacob S. Siegel and David a. Swanson (2004): The Methods and Materials of Demography, Second Edition, Chapters 1, 2, 3, 7, 9,10, Elsevier Science, USA.
4. Asha A. Bhende and Tara Kanitkar, (2003), Principles of Population Studies, Sixteenth Revised Edition, Himalaya Publishing House, Mumbai.
5. John R. Weeks, (2005), Population: An Introduction to Concepts and Issues, Nineth Edition, Wadsworth Publishing Company, Belmont, California.
6. Ram, F. and K.B. Pathak (1998): Techniques of Demographic Analysis,2ndEd, Himalaya Publishing house, Bombay(Chapters 2 & 3).
7. United Nations, (1974): Methods of Measuring Internal Migration, Manual VI, UN, New York.
8. United Nations, (2004): World Urbanization Prospects, The 2003 Revision, New York.
9. Makridakis, S. Steven C., Wheelwright, and Rob J. Hyndman (1998): Forecasting: Methods and Applications, New York: John Wiley and Sons, p607-.
10. Jacob S. Siegel and David a. Swanson (2004): The Methods and Materials of Demography, Second Edition, Chapters 1, 2, 3, 7, 9,10, Elsevier Science, USA.
11. Murray C. J. L., J. A. Salomon, C. D. Mathers and A. D. Lopez (2002). Summary Measures of Population Health: Concepts, Ethics, Measurement and Applications. WHO, Geneva.

Course Title: Econometrics **DSE-1 Course: V (Semester-V)**

Course Code: 23US5STDS1ECO **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Deepen and broaden student's knowledge and understanding of basic econometric techniques needed for empirical quantitative analysis.
Course Outcomes:	**By the end of this course, learner will able to** 1) .Describe consumer behaviour. 2) Apply concepts of statistics in economic models

Module – 1	**Econometric Methods and Models**	**12 Lect**
	Learning Objectives: The module is intended to. 1) Illustrate different models	
	Learning Outcomes: By the end of this module, learner will able to 1) Estimate the parameters of the model 2) State the properties of estimators 3) Apply tests of significance	
a)	Definition & Scope	
b)	Nature of Econometric Approach	
c)	Methodology & Econometric Research	
d)	Econometric Models & Single Equation Models	

Module – 2	**Application of Single Equation Technique**	**12 Lect**
	Learning Objectives: The module is intended to 1) Familiarize students with application of single equation techniques.	
	Learning Outcomes: By the end of this module, learner will able to 1) Estimate the demand & production functions	

	2) Apply concepts of forecasting	
a)	Heteroscedasticity, Multicollinearity & Autocorrelation	
b)	Statistical Estimation of Demand Function	
c)	Statistical Estimation of Production Function	

Module – 3	**Input-Output Analysis**	**12 Lect**
	Learning Objectives: The module is intended to 1) Apply statistics in dynamic models	
	Learning Outcomes: By the end of this module, learner will able to 1) State the assumptions. 2) Test the validity of the assumptions. 3) Analyse the closed & dynamic model.	
a)	The Inter-Industry Accounting System ,Assumptions	
b)	Closed Model & Dynamic Model	

References:

1. P. V. Borwankar, Econometrics: An Introductory Analysis, Sheth Publishers pvt. Ltd. 2. Gujarati, Damodar and Sangeetha (2011), Basic Econometrics, McGraw Hill, Fifth Edition
2. Mankiw, N. G. (2002), Principles of Economics, Thomson Asia Pte. Ltd., Singapore.
3. Pindyck, R, Rubinfeld and Mehta (2011), Microeconomics, Pearson Prentice Hall, 7th Edition
4. Salvatore, D., (2006) Microeconomics: Theory and Applications, Oxford University Press, New Delhi.
5. D'Souza Errol, (2012), Macroeconomics, Dorling Kindersley India pvt. Ltd.- Pearson Education, second edition Mankiw
6. Edward Dowling (2011), Schaum's Outline of Introduction to Mathematical Economics, McGraw Hill Education, Third Edition

Discipline Specific Elective-2 (Sem-V)

Course Title: Operation research-II **DSE-2 Course: VI (Semester-V)**

Course Code: 23US5STDS2OPR2 **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) To help students make correct decisions in real life market circumstances.
Course Outcomes:	**By the end of this course, learner will able to** 1) Estimate the no. of units to be kept in stock keeping in view the cost constraints in various situations. 2) Select appropriate replacement policy. 3) Make the best decision under different decision-making situations.

Module – 1	**INVENTORY CONTROL**	**18 Lect**
	Learning Objectives: The module is intended to 1) Set up various models under deterministic & probabilistic situations in maintaining appropriate stock & minimizing cost.	
	Learning Outcomes: By the end of this module, learner will able to 1) Identify different types of cost involved. 2) Compute the quantity of units to be produced or to be kept in inventory. 3) Measure the minimum cost/expected cost. 4) Specify the time for the next order.	
a)	**Deterministic Models:** Single item static EOQ models for: (i) Constant rate of demand with instantaneous replenishment, with and without shortages. (ii) Constant rate of demand with uniform rate of replenishment, with and without shortages. (iii) Constant rate of demand with instantaneous replenishment without shortages, with at most two price breaks.	

b)	**Probabilistic models:** Single period with (i) Instantaneous demand (discrete and continuous) without setup cost. (ii) Uniform demand (discrete and continuous) without set up cost.	

Module – 2	**REPLACEMENT**	**07 Lect**
	Learning Objectives: The module is intended to 1) Enable learners to plan for replacement of items taking in view the various cost constraints.	
	Learning Outcomes: By the end of this module, learner will able to 1) Formulate cost functions under different situations. 2) Compute the time of replacement of items. 3) Calculate the costs for individual and group replacements. 4) Choose the appropriate replacement policy.	
a)	Replacement of items that deteriorate with time and value of Money i) remains constant ii) changes with time.	
b)	Replacement of items that fail completely: Individual replacement and Group replacement policies.	

Module – 3	**DECISION THEORY**	**11 Lect**
	Learning Objectives: The module is intended to 1) Select the best decision under different decision making situations.	
	Learning Outcomes: By the end of this module, learner will able to 1) Demonstrate the various decision making criteria. 2) Employ the correct decision criteria. 3) Critically evaluate the decision taken under a given situation..	
a)	**Decision making under uncertainty:** i) Laplace criterion ii) Maximax (Minimin) criterion	

	iii) Maximin (Minimax) criterion iv) Hurwicz criterion v) Minimax Regret criterion.	
b)	**Decision making under risk:** i) Expected Monetary Value criterion, ii) Expected Opportunity Loss criterion, iii) EPPI iv) EVPI v) Bayesian Decision rule for Posterior analysis. vi) Decision tree analysis along with Posterior probabilities.	

References:

1. N. D. Vora : Quantitative Techniques in Management, Third edition, McGraw Hill Companies
2. Banerjee B. : Operation Research Techniques for Management, First edition, Business books
3. Bronson R. : Theory and problems of Operations research, First edition, Schaum's Outline series
4. Kanti Swarup, P.K. Gupta, Manmohan : Operations Research, Twelfth edition, Sultan Chand & sons
5. S. D. Sharma: Operations Research, Eighth edition, Kedarnath Ramnath & Co.

Course Title: Linear Models **DSE-2 Course: VI (Semester-V)**

Course Code: 23US5STDS2LIM **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Introduce linear models with the help of matrix theory.
Course Outcomes:	**By the end of this course, learner will able to** 1) Do basic operations on matrices. 2) Construct appropriate linear models and test the hypothesis of the parameters. 3) Analyse a Co-variance matrix.

Module – 1	**Matrix Theory**	**12 Lect**
	Learning Objectives: The module is intended to 1) Revise matrix theory	
	Learning Outcomes: By the end of this module, learner will able to 1) Calculate the inverse & generalized inverse of a matrix. 2) Re-write the matrix in canonical forms. 3) Specify the eigen values & eigenvectors of a matrix.	
a)	Basic operations, determinants, inverse and rank of a matrix, canonical forms.	
b)	Solving linear equations, generalized inverse.	
c)	Partitioned matrices, its determinant and inverse.	
d)	Eigenvalues and Eigenvectors of a matrix.	

Module – 2	**The General Linear Model**	**12 Lect**
	Learning Objectives: The module is intended to 1) Help formulate the general linear model and check its adequacy.	
	Learning Outcomes: By the end of this module, learner will able to 1) Construct appropriate general linear model	

	2) Calculate interval for estimates of the parameters. 3) Test relevant hypothesis of the parameters.	
a)	Linear parametric function and its estimability.	
b)	Gauss-Markoff theorem.	
c)	Interval estimates and test of hypothesis.	
d)	Fundamental theorems on conditional error s.s.	
e)	Test of $\Lambda\beta=d$.	

Module – 3	**Analysis of Covariance(ANCOVA)**	**12 Lect**
	Learning Objectives: The module is intended to 1) Analyse general linear model when observations are correlated.	
	Learning Outcomes: By the end of this module, learner will able to 1) Analyse a covariance matrix in case of one-way & two-way classification.	
	Introduction Model BLUE ANCOVA Table Testing if hypothesis One way ANCOVA	

References:

1. Hohn Franz E: Elementary Matrix Algebra
2. Searle S.R.: Matrix Algebra useful for Statistics
3. Kshirsagar A.M.: A course in Linear Models
4. Draper N.R & Smith H: Applied Regression Analysis.
5. Song GUI Wang and S.C Chow: Advanced Linear Models.

Skill Enhancement Course (Sem-V)

Course Title: SQL and R-Programming **Course: VII (Semester-V)**

Course Code: 23US5STSECSQR **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Set up SQL commands 2) Practice SQL functions 3) Set up simple R- commands 4) Practice R functions
Course Outcomes:	**By the end of this course, learner will able to** 1) Establish SQL query for relational database 2) Use SQL functions 3) Write Simple R-commands to calculate various statistical measures 4) Write R-commands for testing of hypothesis and ANOVA

Module – 1	**Introduction to RDBMS and SQL**	**12 Lect**
	Learning Objectives: The module is intended to 1) Set up SQL commands 2) Practice SQL functions	
	Learning Outcomes: By the end of this module, learner will able to 1) Establish SQL query for relational database 2) Use SQL functions	
a)	Definition of relational database and SQL. SQL Data types: Numeric, Date and Time, String	
b)	SQL commands: DDL (CREATE, ALTER, DROP), DML (INSERT, UPDATE, DELETE), DQL (SELECT) Keys: Primary, Foreign Constraints: NOT NULL, DEFAULT, UNIQUE, PRIMARY Key, FOREIGN Key, CHECK, INDEX	
c)	SQL Functions: Group functions (AVG, SUM, MIN, MAX, COUNT), DATE Functions, String functions, Numeric functions	

	(ABS, EXP, LOG, SQRT, POWER, SIGN, ROUND)	
d)	Joining tables: Inner, Outer and Cross Joins, UNION	

Module – 2	**Introduction to R-Commands and functions**	**12 Lect**
	Learning Objectives: The module is intended to 1) Acquire knowledge about various R commands and functions for statistical computing	
	Learning Outcomes: By the end of this module, learner will able to 1) Construct various methods of inputting data and built-in functions 2) Provide accurate graphs and diagrams 3) Construct R-commands for computing various statistical constants 4) Construct R-commands for various discrete and continuous probability distributions 5) Construct R-commands for various methods of sampling 6) Develop R-commands for computing p-values required in study of estimation and testing of hypothesis 7) Solve analysis of one-way and two-way classification using R 8) Write simple R-programs	
a)	Methods of data input: c function, Sequence operator and seq function, scan function, rep function, data.frame function, matrix function, class function, Importing data from Excel.	
b)	Built-in functions: length(), max(), min(), range(), sum(), cumsum(), mean(), median(), var(), sort()	
c)	Diagrammatic and Graphical representation of data,	
d)	Descriptive Statistics using R software: Frequency table (univariate and bivariate),Measures of central tendency, dispersion, moments, skewness and kurtosis, Correlation and regression analysis	
e)	Discrete probability distributions: Binomial, Poisson,	

	Hypergeometric	
f)	Continuous probability distributions: Normal distribution, t-distribution, chi-square distribution, exponential distribution	
g)	Sampling methods: SRSWR, SRSWOR, stratified random sampling, systematic sampling	
h)	Testing of hypothesis: Normality check, Parametric and non-parametric	
i)	Analysis of variance: One way classification, Two way classification	
j)	R as a programming language: Grouping, loops and conditional execution, Functions	

References:

Sem-VI

Course Title: Reliability and Survival Analysis **Core Course: I (Semester-VI)**

Course Code: 23US6STCC1RSA **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Acquaint students with the concepts such as Survival analysis, Reliability theory, Censoring and Non-parametric estimation of Survival function
Course Outcomes:	**By the end of this course, learner will be able to** 1) Obtain survival function, hazard function and the nature of the hazard function from the survival data 2) Compute reliability of the system 3) Understand different types of censoring 4) Compute K-M estimator of survival function

Module – 1	**Introduction to Survival Analysis**	**12 Lect**
	Learning Objectives: The module is intended to 1) Explain basic concepts in survival analysis 2) Understand survival analysis in real life problems	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand the need of Survival analysis 2) Find survival function and hazard function from the survival data 3) Identify the nature of hazard function 4) Apply concepts of survival analysis in real life problems	
a)	**Basic concepts:** pdf, cdf, survival function, Hazard function, cumulative hazard function, reversed hazard function, Bathtub shaped hazard function Relations between survival function, probability function, hazard function, cumulative hazard function, reversed hazard function Some Lifetime distributions: Exponential, Weibull, Gamma, Gumbel, Pareto etc.	

b)	**Aging properties:** Definitions of IFR (Increasing Failure Rate), DFR (Decreasing Failure Rate), CFR (Constant Failure Rate), NBU (New Better than Used) and NWU (New Worse than Used) components of lifetime distributions	
c)	Mean time to failure (MTTF), Mean residual life time	

Module – 2	**Introduction to Reliability Theory**	**12 Lect**
	Learning Objective: **The module is intended to** 1) Understand the concept of Reliability 2) Understand different types of systems	
	Learning Outcomes: By the end of this module, learner will able to 1) Compute reliability and Equivalent structure of the system. 2) Apply reliability concepts in real life.	
a)	Concept of Reliability, Definition of system, structure function.	
b)	**Standard systems:** Series, Parallel, 2 out of 3 system, k out of n system, coherent system.	
c)	**Equivalent structure for any system:** Path set, Minimal path set, Path vector, Minimal path vector, cut set, Minimal cut set, Cut vector, Minimal cut vector, Reliability bounds.	

Module – 3	**Censoring and Non-parametric estimation of survival function**	**12 Lect**
	Learning Objective: The module is intended to 1) Introduce the concept of censoring and Non-parametric estimation of survival function	
	Learning Outcome: By the end of this module, learner will able to 1) Understand the concept of censoring 2) Understand different types of censoring 3) Compute Kaplan-Meier (K-M)estimator of survival function and Nelson-Aalen estimator of cumulative hazard function	
a)	**Concept of censoring:** Type-I, Type-II, Left random, right random	

	, Interval and hybrid censoring	
b)	**Non-parametric estimation of survival function:** Kaplan-Meier (K-M) estimator, Properties of KM estimator, Approximate mean and variance of KM estimator, Nelson-Aalen estimator of cumulative hazard function	
c)	Linear confidence intervals for survival function and cumulative hazard function	

References:

1. Smith P.J. (2002): Analysis of Failure and Survival data, Florida: CRC Press
2. Deshpande J.V. and Purohit S.G. (2005): Lifetime Data: Statistical Models and Methods, Pune: Word Scientific
3. Barlow R.E. and Proschan F (1965): Mathematical theory of reliability, New York: John Wiley
4. Barlow R.E. and Proschan F (1975): Statistical theory of reliability and life testing: Probability models, New York: Holt, Rinehart and Winston
5. Ross S.M. (1993): Introduction to Probability Models, United States: Academic Press (Elsevier)
6. Cox DR, Oakes D. (2001): Analysis of survival data , London, England: Chapman and Hall

Course Title: Testing of hypothesis **Core Course: II (Semester-VI)**

Course Code: 23US6STCC2TOH **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Define and distinguish between various types of Parametric and nonparametric testing of hypothesis methods.
Course Outcomes:	**By the end of this course, learner will able to** 1) Understand different types of hypotheses and obtain the powerful critical region in case of parametric testing of hypothesis. 2) Test the hypothesis about the population parameter when the sample size is not fixed. 3) Test the hypothesis when the form of the population distribution is not known.

Module – 1	**Most Powerful Tests, Uniformly Most Powerful & Likelihood Ratio Tests**	**16 Lect**
	Learning Objectives: The module is intended to 1) Know different types of hypothesis in case of parametric population. 2) Learn the techniques of testing for different types of hypothesis.	
	Learning Outcomes: By the end of this module, learner will able to 1) Frame the proper hypothesis as per the situation. 2) Use the proper critical region to test the hypothesis. 3) Obtain types of errors, power of the test	
a)	Definitions and illustrations of i) Simple hypothesis ii) Composite hypothesis iii)Null Hypothesis iv) Alternative Hypothesis v)Test of hypothesis vi) Critical region vii) Type I and Type II errors viii) Level of significance ix) p-value x) Size of the test xi) Power of the test xii) Power function of a test xiii) Power curve.	

b)	Definition of most powerful test of size α for a simple hypothesis against a simple alternative hypothesis. Neyman-Pearson fundamental lemma.	
c)	Definition, Existence and Construction of Uniformly most powerful (UMP)	
d)	Likelihood ratio principle: Definition of test statistic and its asymptotic distribution (statement only). Construction of LRT for the mean of Normal distribution for (i) Known σ2 (ii) Unknown σ2 (two sided alternatives).LRT for variance of normal distribution for (i) known μ (ii) unknown μ (two sided alternatives hypothesis)	

Module – 2	**Sequential Probability Ratio Test (SPRT)**	**10 Lect**
	Learning Objectives: The module is intended to 1) Test the hypothesis in case of parametric population when the sample size is not fixed**.**	
	Learning Outcomes: By the end of this module, learner will able to 1) Establish the best critical region under various distributions when sample size is not fixed in advance. 2) Draw graph to represent critical region and acceptance region and interpret the information**...**	
a)	Sequential test procedure for testing a simple null hypothesis against a simple alternative hypothesis. Its comparison with fixed sample size (Neyman-Pearson) test procedure.	
b)	Definition of Wald's SPRT of strength (α, β). Operating Characteristic function of SPRT (O.C.) Average Sample Number (A.S.N.)	
c)	Problems based on Bernoulli, Binomial, Poisson, Normal, Exponential distributions.	
d)	Graphical /tabular procedure for carrying out the tests.	

Module – 3	**Non-Parametric Tests**	**10 Lect**
	Learning Objectives: The module is intended to 1) Test the hypothesis in case of non-parametric population.	
	Learning Outcomes: By the end of this module, learner will able to 1) Distinguish between distribution-free tests and parametric test for testing statistical hypotheses. 2) Construct most common methods and techniques of nonparametric statistics (signed tests, ranked tests, run test etc.).	
a)	Need for non-parametric tests. Distinction between a parametric and a non-parametric test. Concept of a distribution free statistic.	
b)	Single sample and two sample non-parametric tests. (i) Sign test (ii) Wilcoxon's signed rank test (iii) Median test (iv) Mann–Whitney test (v) Run test.	

References:

1) Hogg R.V. and Craig A.T: Introduction to Mathematical Statistics Fourth edition London Macmillan Co. Ltd.
2) Hogg R.V. and Tanis E.A.: Probability and Statistical Inference. Third edition Delhi Pearson Education.
3) Lehmann, E. L: Testing of Statistical Hypothesis, Wiley & Sons
4) Rao, C. R.: Linear Statistical Inference.
5) Daniel W.W.: Applied Non Parametric Statistics First edition Boston-Houghton Mifflin Company.
6) Wald A.: Sequential Analysis First edition New York John Wiley & Sons
7) Biswas S.: Topics in Statistical Methodology. First edition New Delhi Wiley eastern Ltd.
8) Gupta S.C. and Kapoor V.K.: Fundamentals of Mathematical Statistics Tenth edition New Delhi S. Chand & Company Ltd.
9) Sanjay Arora and BansiLal: New Mathematical Statistics, SatyaPrakashan, New Market, New Delhi, 5(1989).

Course Title: Stochastic Process **Core Course: III (Semester-VI)**

Course Code: 23US6STCC3STP **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Understand different types of stochastic processes. 2) Understand different types queuing models.
Course Outcomes:	**By the end of this course, learner will able to** 1) Obtain probability distributions of different stochastic processes. 2) Obtain Transition probabilities in Markov Chain 3) Classify states of Markov Chain. 4) Obtain probability distribution for queuing models. 5) Derive characteristics of queuing models.

Module – 1	**STOCHASTIC PROCESSES**	**12 Lect**
	Learning Objectives: The module is intended to 1) Understand different types of stochastic processes.	
	Learning Outcomes: By the end of this module, learner will able to 1) Obtain probability distributions of different stochastic processes.	
a)	Definition of stochastic process.	
b)	**Postulates and difference differential equations for :** i) Pure birth process ii) Poisson process with initially 'a' members, for a = 0 and a >0 iii) Yule Furry process iv) Pure death process v) Death process with $\mu_n=\mu$ vi) Death process with $\mu_n=n\mu$ vii) Birth and death process	

	viii) Linear growth model.	
c)	Derivation of Pn(t), mean and variance wherever applicable	

Module – 2	**MARKOV CHAIN**	**14 Lect**
	Learning Objectives: The module is intended to 1) Know applications of Markov chain	
	Learning Outcomes: By the end of this module, learner will able to 1) To Understand the concept of dependence of random variables 2) To calculate probabilities from one step transition probability matrix 3) To apply concept of Markov Chain in real life problems.	
a)	Definition of Markov Chain, transition probability matrix, order of Markov chain, first order Markov property, Markov chains (MC), finite MC, time homogeneous M.C.	
b)	One step transition probabilities and transition probability matrix (t.p.m.), stochastic matrix, Chapman Kolmogorov equation, n-step transition probability matrix and some typical t. p. m., initial distribution	
c)	Finite dimensional distribution functions , partial sum (and functions) of independent and identically distributed random variables as Markov chain, illustrations such as Gambler's ruin problem, Ehrenfest chain	
d)	Communicating states , first return probability, probability of ever return Classification of states, as persistent and transient states, irreducible MC, period of states, stationary distribution.	

Module – 3	**QUEUING THEORY**	**10 Lect**
	Learning Objectives: The module is intended to 1) Identify different types of queuing models	
	Learning Outcomes: By the end of this module, learner will able to	**12 Lect**

	1) Obtain probability distribution for queuing models. 2) Derive characteristics of queuing models.	
a.	Basic elements of the Queuing model.	
b.	Roles of the Poisson and Exponential distributions.	
c.	Derivation of Steady state probabilities for birth and death Process.	
d.	**Steady state probabilities and various average characteristics for the following models:** (i) (M/M/1) : (GD/ ∞ /∞) (ii) (M/M/1) : (GD/ N/∞) (iii) (M/M/c) : (GD/∞/∞) (iv) (M/M/c) : (GD/ N /∞) (v) (M/M/∞) : (GD/ ∞ /∞)	

References:

1. Medhi J. (2002) : Stochastic Processes, Second edition, Wiley Eastern Ltd.
2. Hoel , P.G.,Port, S.C. ,Stone, C.J. (1972) : Introduction to stochastic processes
3. Kantiswarup, P. K. Gupta, Manmohan (1977) : Operations Research, Twelth edition, Sultan Chand & sons
4. Sharma S. D. (1974) : Operations Research, Eighth edition, Kedarnath Ramnath & Co.
5. Basu A. (2003) : An introduction to Stochastic Processes, Alpha Science International

Course Title: Elements of actuarial science **Core Course: IV (Semester-VI)**

Course Code: 23US6STCC4EAS **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Differentiate different types of annuities and assurance plan 2) Compute present and accumulated value of money under different types of annuities 3) Compute and compare level annual premium under different assurance plan
Course Outcomes:	**By the end of this course, learner will able to** 1) Establish relation between nominal and effective rate of interest 2) Determine present value and accumulated value for different types of annuity certain 3) Determine present value for different types of life annuities in terms of commutation functions 4) Formulate Single premium and level annual premium under different assurance plan

Module – 1	**Annuity Certain**	**12 Lect**
	Learning Objectives: The module is intended to 1) Compute value of money, at different time periods, using nominal and effective rate of interest, for annuity certain	
	Learning Outcomes: By the end of this module, learner will able to 1) Correlate between nominal and effective rate of interest 2) Determine present value and accumulated value for different types of annuity certain 3) Assess interest, principal contained in m^{th} yearly installment and principal outstanding at the end of m year	
a)	Simple and compound Interest, relation between nominal and effective rate of interest , present value (p.v.), accumulated value	

	(a.v.), discount and discounted value, p.v. and a.v. for varying rates of interest, equation of value	
b)	Annuities: different types of annuity, derivations for p.v. and a.v. of different types of annuities	
c)	Variable annuity: p.v. and a.v. of an increasing annuity of different types, p.v. and a.v. of an increasing annuity certain where successive installments form arithmetic progression/geometric progression.	
d)	p.v. and a.v. of annuity, where i) payments are made 'p' times a year ii) payments of amount y are made at each interval of 'r' years.	
e)	Redemption of loan: Derivation for i) interest contained in m^{th} yearly installment ii) principal contained in the m^{th} yearly installment iii) principal outstanding at the end of m years	

Module – 2	**Life annuity**	**12 Lect**
	Learning Objectives: The module is intended to 1) Compute value of money, at different time periods, using nominal and effective rate of interest, for life annuity.	
	Learning Outcomes: By the end of this module, learner will able to 1) Write commutation functions 2) Define different types of life annuities 3) Determine present value for different types of life annuities in terms of commutation functions	
a)	Commutation functions, p.v. of an immediate life annuity and life annuity due, p.v. of deferred immediate life annuity and life annuity due	
b)	p.v. of temporary immediate life annuity and life annuity due, p.v. of deferred temporary immediate life annuity and life annuity due	
c)	p.v. of increasing temporary immediate life annuity and life annuity due	

d)	Life annuity payable m times in a year	

Module – 3	**Assurance benefits and Net premiums**	**12 Lect**
	Learning Objectives: The module is intended to 1) Compute assurance benefits and level annual premium under different assurance plan	
	Learning Outcomes: By the end of this module, learner will able to 1) Recognise different assurance plans 2) Determine single premium under different assurance plans 3) Determine level annual premium under different assurance plans	
a)	Derivations for p.v. of benefits (single premium) under various assurance plans i) temporary assurance ii) Whole life assurance iii) Pure endowment assurance iv) Endowment assurance v) Double endowment assurance vi) Increasing temporary assurance vii) Increasing whole life assurance viii) Special endowment assurance ix) Deferred temporary assurance x) deferred whole life assurance	
b)	Derivations for level annual premium under various assurance plans i) temporary assurance ii) Whole life assurance iii) Pure endowment assurance iv) Endowment assurance v) Double endowment assurance	

References:

1. Neill A. : Life Contingencies, First edition, Heineman educational books London
2. Dixit S.P., Modi C.S., Joshi R.V. : Mathematical Basis of Life Assurance, First edition Insurance Institute of India.
3. E. Freund and FJ William, Modern Business, Statistics.
4. A.M. Goon, M. K. Gupta and B. Das Gupta, Fundamentals of Statistics, Vol. I and II

Discipline Specific Elective-1 (Sem-VI)

Course Title: Data Mining and Statistical Learning **DSE-1 Course: V (Semester-VI)**

Course Code: 23US6STDS1DMS **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Understand different data types and visualization techniques. 2) Learn different algorithms and analyze the data and validate model 3) Apply clustering and frequent pattern mining
Course Outcomes:	**By the end of this course, learner will able to** 1) Understand different visualization techniques to represent data in a systematic way 2) Understand and apply the classification algorithm on dataset 3) Understand and apply the prediction algorithm 4) Understand the concept of clustering and apply on dataset to form clusters 5) Apply Association mining rules on dataset

Module – 1	**Introduction to data mining (DM)**	**12 Lect**
	Learning Objectives: The module is intended to 1) Introduce different data types and visualization techniques.	
	Learning Outcomes: By the end of this module, learner will able to 1) Learn to Understand the data mining and various applications and issues 2) Understand different visualization techniques to represent data in a systematic way 3) Learn to prepare various types of data.	
a)	What is Data Mining; Knowledge Discovery in Database (KDD), What can be Data to be Mined, Related Concept to Data Mining, Data Mining Technique, Application and Issues in Data Mining	
b)	Types of Attributes; Statistical Description of Data; Data	

	Visualization; Measuring similarity and dissimilarity.	
c)	Why Preprocessing? Data Cleaning; Data Integration; Data Reduction: Attribute subset selection, Histograms, Clustering and Sampling; Data Transformation & Data Discretization: Normalization, Binning, Histogram Analysis and Concept hierarchy generation	

Module – 2	**Classification and Prediction**	**12 Lect**
	Learning Objectives: The module is intended to 1) Learn different algorithms and analyze the data and validate model	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand and apply the classification algorithm on dataset 2) Understand and apply the prediction algorithm.	
a)	Basic concepts, what is supervised and unsupervised methods, difference between classification and prediction tasks. Decision Tree Induction: Attribute Selection Measures, Tree pruning. Bayesian Classification: Naïve Bayes' Classifier	
b)	Prediction methods: Linear and nonlinear regression, Logistic Regression	
c)	Accuracy and Error measures, Precision, Recall, Holdout, Random Sampling, Cross Validation.	

Module – 3	**Clustering and Frequent pattern mining**	**12 Lect**
	Learning Objectives: The module is intended to 1) Apply clustering and frequent pattern mining	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand the concept of clustering and apply on dataset to form clusters 2) Apply Association mining rules on dataset	

a)	Cluster Analysis: Basic Concepts Partitioning Methods: K-Means, KMediods; Hierarchical Methods: Agglomerative, Divisive, BIRCH; Density-Based Methods: DBSCAN	
b)	Market Basket Analysis, Frequent Itemsets, Closed Itemsets, and Association Rules; Frequent Pattern Mining, The Apriori Algorithm for finding Frequent Itemsets, pattern growth approach for mining Frequent Itemsets; Mining Frequent Itemsets using vertical data formats; Introduction to Mining Multilevel Association Rules and Multidimensional Association Rules, Correlation Analysis, lift.	

References:

1. Han, Kamber, "Data Mining Concepts and Techniques", Elsevier, 2nd edition
2. Galit Shmueli, Nitin Patel, Peter Bruce, (2010). Data Mining for Business Intelligence: Concepts, Techniques, and Applications in Microsoft Office Excel with XLMiner , Wiley
3. Breiman, L., Friedman, J.H., Olshen, R.A. and Stone, C.J. (1984). Classification and Regression Trees.(Wadsworth and Brooks/Cole).
4. Daniel T.Larose, (2006). Data Mining Methods and Models. Wile-Interscience.
5. Hastie T., Tibshirani R. and Friedman J. H., (2003). The Elements of Statistical Learning: Data Mining, Inference and Prediction. Springer
6. Mitchell Tom, (1997). Machine Learning McGraw-Hill

Course Title: Biostatistics **DSE-1 Course: V (Semester-VI)**

Course Code: 23US6STDS1BST **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Introduce applications of statistics in the field of medical science
Course Outcomes:	**By the end of this course, learner will able to** 1) Find the rate at which infection spreads for a given epidemic. 2) Evaluate statistically the significance of the treatments given. 3) Formulate appropriate study design to estimate different parameters and analyze the results.

Module – 1	**Epidemic Models**	**12 Lect**
	Learning Objectives: The module is intended to 1) Illustrate different deterministic and probabilistic models for estimating susceptibles and infectives in a given population.	
	Learning Outcomes: By the end of this module, learner will able to 1) Define the terms involved in epidemics. 2) Explain the stages of epidemics. 3) Differentiate between deterministic and probabilistic models. 4) Compute the no. of susceptibles and infectives in case of deterministic models. 5) Estimate the probability of infectives in case of probabilistic models.	
a)	The features of Epidemic spread. Definitions of various terms involved. Simple mathematical models for epidemics: Deterministic model without removals, Carrier model, host vector model, threshold value for population sizes.	
b)	Chain binomial models. Reed - Frost and Greenwood models. Distribution of individual chains and total number of cases.	

	Maximum likelihood estimator of 'p' using method of scores and its asymptotic variance for households of sizes up to 4.	

Module – 2	**Bioassays**	**10 Lect**
	Learning Objectives: The module is intended to 1) Enable learners to analyze the usefulness of drugs based on the response of the subjects.	
	Learning Outcomes: By the end of this module, learner will able to 1) Define and differentiate terms involved in bioassay. 2) Differentiate between qualitative & quantitative assay. 3) Evaluate & Compare the potency of different drugs. 4) Recommend the appropriate method of analyzing the potency.	
a)	Meaning and scope of bioassays. Relative potency, Direct assays. Fieller's theorem.	
b)	Indirect assays. Dose-response relationship .Condition of similarity and Monotony. Linearizing transformations. Parallel line assays & Slope Ratio assay (Concept Only).	
c)	Quantal Response assays. Tolerance distribution. Median effective dose ED50 and LD50 using Probit analysis and logit analysis.	

Module – 3	**CLINICAL TRIALS & BIO-EQUIVALENCE**	**14 Lect**
	Learning Objectives: The module is intended to 1) Explain the theory of clinical trials and methods to prove bioequivalence.	
	Learning Outcomes: By the end of this module, learner will able to 1) Illustrate different stages of clinical trials. 2) Devise proper questionnaires and estimate the required sample size. 3) Recommend appropriate study design. 4) Assess the effectiveness of treatments.	

	5) Estimate the different PK parameters. 6) Analyze whether the drug is bio-equivalent.	
a)	Introduction to clinical trials: The need and ethics of clinical trials. Common terminology used in clinical trials. Overview of phases (I-IV). Study Protocol, Case record/Report form, Blinding (Single/Double) Randomized controlled (Placebo /Active controlled), Study Designs (Parallel, Cross Over).	
b)	Types of Trials: Inferiority, Superiority and Equivalence, Multi-centric Trial. Inclusion/Exclusion Criteria. Statistical tools: Analysis of parallel Design using Analysis of Variance.	
c)	Concept of odds ratio. Sample size estimation.	
d)	Definitions of Generic Drug product. Bioavailability, Bioequivalence, Pharmacokinetic (PK) parameters Cmax, AUCt, AUC0-infinity, Tmax, Kel, Thalf. Estimation of PK parameters using 'time vs. concentration' profiles.	
e)	Analysis of Parallel design using logarithmic transformation (Summary statistics, ANOVA and 90% confidence interval).	
f)	Confidence Interval approach to establish bioequivalence (80/125 rule).	

References:

1. Bailey N.T.J.: The Mathematical theory of infectious diseases, Second edition, Charles Griffin and Co. London.
2. Das M.N and Giri N.C. : Design and Analysis of Experiments, Second edition, Wiley Eastern
3. Finney D.J. : Statistical Methods in Biological Assays, First edition, Charles Griffin and Co. London
4. Zar Jerrold H.: Biostatistical Analysis, Fourth edition, Pearson's education.
5. Daniel W.D. Biostatistics
6. Friedman L. M., Furburg C., Demets D. L. (1998): Fundamentals of Clinical Trials, First edition, Springer Verlag.
7. Fleiss J. L. (1989). The Design and Analysis of Clinical Experiments, Second edition, Wiley and Sons
8. Shein-Chung-Chow: Design and Analysis of Bioavailability & Bioequivalence studies, Third Edition, Chapman & Hall/CRC Biostatistics series.

Discipline Specific Elective-2 (Sem-V)

Course Title: Time Series Analysis **DSE-2 Course: V (Semester-VI)**

Course Code: 23US6STDS2TSA **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) To introduce the concept of time series analysis. 2) To enable students with the concept of stationarity, ACF, PACF in time series analysis. 3) To understand and apply time series modeling. 4) To enable students with the concept of smoothing and to introduce different smoothing techniques.
Course Outcomes:	By the end of this course, learner will be able to 1) Analyze the time series data and can separate the different components of time series. 2) Check stationarity of given time series data. 3) Plot and interpret ACF and PACF graphs. 4) Fit different time series models to the given time series data using the concept of time series modeling. 5) Apply different smoothing techniques on real life data.

Module – 1	**Introduction to Time Series Analysis**	**12 Lect**
	Learning Objectives: The module is intended to 1) Revise basic concepts in time series analysis 2) Enable students with the concept of stationarity in time series analysis 3) Introduce the concept of ACF and PACF	
	Learning Outcomes: By the end of this module, learner will able to 1) Analyze the time series data and can separate the different components of time series	

	2) Understand the concept of stationarity 3) Plot and Interpret ACF and PACF graphs for given time series data	
a)	Introduction to time series analysis, Components of a time series, Decomposition of a time series	
b)	Stationary time series, Problems based on stationarity, Importance of stationary time series, Methods to convert non-stationary time series into stationary time series, Assessing stationarity of TS using time series plot, correlogram, D-F test	
c)	Autocovariance function, Properties of autocovariance function, Autocorrelation function, Problems based on acf, Correlogram, Testing for significance of autocorrelation, Partial acf	
d)	Special type of time series models	

Module – 2:	**Time Series Modeling**	**12 Lect**
	Learning Objectives: The module is intended to 1) Enable students with the concept of time series modeling 2) Introduce some stationary time series models 3) Obtain ACF and PACF of some stationary time series models 4) Estimate parameters of AR process using different methods of estimation	
	Learning Outcomes: By the end of this module, learner will able to 1) Understand the importance of time series modeling and the methodology 2) Fit different stationary time series models on real life data 3) Identify stationary time series models using ACF and PACF graphs	
a)	Introduction to time series modeling, Box-Jenkins methodology, Autoregressive (AR) process, Moving average (MA) process, ARMA process, ARIMA process	
b)	ACF and PACF of AR(1), AR(2), MA(1), MA(2) , ARMA(1,1)	

	process	
c)	Estimation of parameters of AR(1), AR(2) processes using least square estimation method, MOM method, MLE method	

Module – 3	**Smoothing Techniques**	**12 Lect**
	Learning Objective: The module is intended to 1) Enable students with the concept of smoothing 2) Introduce different smoothing techniques	
	Learning Outcome: By the end of this module, learner will able to 1) Understand the concept of smoothing 2) Apply different smoothing techniques on real life data	
a)	Introduction to smoothing, Moving average, Weighted moving average smoothing technique	
b)	Introduction to exponential smoothing, First-order exponential smoothing, Second-order exponential smoothing, Holt's exponential smoothing, Holt and Win ter's exponential smoothing	

References:

1. Brockwell, P.J. and Davis, R. A. (2003): Introduction to Time Series Analysis,Springer
2. Chatfield, C. (2001): Time Series Forecasting, Chapman &Hall.
3. Box George E.P., Jenkins G.M., Reinsel G.C. (2009): Time Series Analysis-Forecasting and control, 3 rd edition, Pearson education
4. Fuller, W. A. (1996): Introduction to Statistical Time Series, 2nd Ed. Wiley.
5. Hamilton N. Y. (1994): Time Series Analysis, Princeton University press.
6. Kendall, M. and Ord, J. K. (1990): Time Series, 3rd Ed. Edward Arnold.
7. Shumway, R. H. and Stoffer, D. S. (2010): Time Series Analysis & Its Applications,Springer.
8. Montgomery, D.C. and Johnson L.A. (1976): Forecasting and Time series analysis,McGraw Hill

Course Title: DESIGNS OF EXPERIMENT-II **Course: DSE-2 (Semester-VI)**

Course Code: 23US6STDS2DOE2 **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Introduce various block designs using matrix theory and split plot design. 2) Understand the concept of confounding.
Course Outcomes:	**By the end of this course, learner will able to** 1) Verify properties of the different block designs. 2) Analyze various designs. 3) Apply the concept of confounding.

Module – 1	**Generalized block design**	**14 Lect**
	Learning Objectives: The module is intended to 1) Explain the analysis of a general block design and its properties.	
	Learning Outcomes: By the end of this module, learner will able to 1) Analyse any general block design. 2) Identify the properties of any design.	
a)	An example of GBD, Statistical analysis of GBD	
b)	Introduction to C-matrix, Properties of design-Connectedness, Orthogonality and Balancedness	
c)	Analysis of RBD with respect to GBD	

Module – 2	**BIBD & Split plot design**	**14 Lect**
	Learning Objectives: The module is intended to 1) Analyse BIBD & Split-Plot design	
	Learning Outcomes: By the end of this module, learner will able to 1) Analyse Balanced Incomplete Block design.	

	2) Justify the use of Split-Plot design in appropriate situations. 3) Analyse Split-Plot design to test for main effects, sub-effects & interaction effects.	
a)	Balanced Incomplete Block Design (BIBD): Concept, Parameters of BIBD, Incidence Matrix, Parametric relations, Symmetry: Necessary & Sufficient Condition, Theorem. Resolvable BIBD & Affine Resolvable BIBD, Properties (Connectedness, Orthogonality, Balancedness), Statistical Analysis of BIBD	
b)	Split plot design, Example, Parameter estimation, Statistical analysis	

Module – 3	**2^k factorial design & Confounding**	**8 Lect**
	Learning Objectives: The module is intended to 1) Discuss the relevance of blocking & confounding and its analysis	
	Learning Outcomes: By the end of this module, learner will able to **1)** Differentiate between total confounding & partial confounding. 2) Confound a 2^k factorial design in 2^p blocks. 3) Identify the confounded treatments. 4) Analyse the confounded design 5) Analyse partially confounded design.	
a)	A single replicate of the 2^k design, Blocking a replicated 2^k factorial design	
b)	Confounding in the 2^k factorial design. Partial confounding.	

References:

1. Montgomery D.C., Design and Analysis of Experiment 8th Edition, John Wiley & Sons.
2. Chakrabarti M.C., Mathematics of Design and Analysis of Experiments.
3. Raghavarao D., Construction and Combinatorial Problems in Design of Experiments.

4. Das. M.M. and Giri N.C., 1986, Design and Analysis of Experiments. New Age International (P) Limited
5. Fisher R.A., Design of Experiments.
6. Dean Voss :-Design and Analysis of Experiments
7. S.C.Gupta and V.K.Kapoor, (2001), Fundamentals of Applied Statistics:; 3rd Edition, Sultan Chand and Sons.
8. B.J. Winer, Statistical Principles in Experimental Design, McGraw Hill Book Company
9. W.G. Cochran and G.M.Cox, Experimental Designs: Second Edition, John Wiley and Sons.
10. Oscar Kempthorne, The Design and Analysis of Experiments, John Wiley and Sons
11. Walter T Federer, Experimental Design, Theory and Application, Oxford & IBH Publishing Co. Pvt.

Skill Enhancement Course (Sem-V)

Course Title: Python programming **Course: VII (Semester-VI)**

Course Code: 23US6STSECPYP **Credits: 02 (36 lectures)**

Course Objectives:	**The course is intended to** 1) Understand Python data types 2) Set up python I/O statements 3) Construct python conditional and looping statements
Course Outcomes:	**By the end of this course, learner will able to** 1) Learn how to do Line to Line Coding. 2) Learn how to write loops and decision statements in Python. 3) Learn how to write functions and pass arguments in Python.

Module – 1	**Introduction to Python data types, data structure and operators, I/O statements**	**12 Lect**
	Learning Objectives: The module is intended to 1) Understand Python data types 2) Set up python I/O statements	
	Learning Outcomes: By the end of this module, learner will able to 1) Learn how to do Line to Line Coding.	
a)	Introduction to Python ● Interpreter v/s compiler ● Installing Anaconda ● Python IDEs, PyCharm, Python IDLE ● Spyderoverview, Jupyter Notebook overview	
b)	• Python Line to Line Coding ● Print statement and print formats ● Data types and Data structures (lists, tuples, dictionaries) ● Python Operators (Mathematical and Logical)	

	● Using help function ● Assignment statements ● Input Output statements	

Module – II	**Python functions, conditional and looping statements**	**12 Lect**
	Learning Objectives: The module is intended to 1) Construct python conditional and looping statements	
	Learning Outcomes: By the end of this module, learner will able to 1) Learn how to write loops and decision statements in Python. 2) Learn how to write functions and pass arguments in Python	
a)	● Conditional statements ● Looping statements	
b)	● Python namespaces and scopes ● Packages and modules, imports ● User defined function	

References:

1. Python in easy steps(2018) : Mike McGrath, BPB publications
2. Python made simple(2019) : Rydhm Beri, BPB publications
3. Let us Python, 5th Edition(2019) : Yashwant Kanetkar and Aditya Kanetkar, BPB publications
4. Basic core python programming(2021) : Meenu Kohli, BPB publications