SEMESTER : 4
COURSE CODE : ST 241
COURSE TITLE : DESIGN AND ANALYSIS OFEXPERIMENTS

COURSE OUTCOME

On completion of the course, students should be able to:
CO1: Identify estimability of a linear parametric function
CO2: Apply Gauss-Markov theorem for finding BLUE of a parametric function
CO3: Understand the methods of model adequacy checking
CO4: Perform one-way and two-way analysis of variances
CO5: Design and analyse CRD, RBD, LSD and GLSD
CO6: Perform analysis of covariance in CRD and RBD
CO7: Perform missing plot and analysis in RBD and LSD
CO8: Construct incomplete block designs
CO9: Analyze BIBD and PBIBD
C10: Design and analyse factorial experiments
C11: Apply principle of total and partial confounding in factorial experiments

MODULE OUTCOME

MODULE	**Module outcomes** *On completion of each module, students should be able to:*	**Taxonomy Level**
MODULE 1	MO1: Identify estimability of a linear parametric function MO2: Apply Gauss-Markov theorem for finding BLUE of a parametric function. MO3: Formulate the model for one way and two way classification MO4: Perform one way and two analysis of variance M05: Understand the methods of model adequacy checking	Understand Apply Understand Analysis Understand
MODULE 1I	MO1: Design and analysis of CRD, RBD, LSD and GLSD MO2: Analysis CRD, RBD and LSD with missing values M03: Perform the analysis of covariance techniques	AnalysisAnalysis Apply
MODULE III	MO1 : Analyze BIBD with inter and intra block informations MO2: Analyse PBIBD with only two associates classes M03: Construct of BIBD M04: Understand lattice designs	Apply Apply Understand Understand
MODULE IV	MO1: Design and analyse of 2^2, 3^n and p^n factorial experiments MO2: Apply principle of total and partial confounding in factorial experiments	Analysis Apply

	M03: Analyze Split-plot M04: Understand the concept of split-split plot and strip-plot designs	Apply Understan d

COURSE CONTENT

Module I

General linear models, estimable function and conditions for estimability, Principle of least squares, Gauss-Markov theorem, sum of squares, distribution of sum of squares, test of linear hypothesis. Basic principles and planning of experiments, one-way ANOVA and two-way ANOVA, fixed effects and random effect models (concept only), Analysis of fixed effect models, model adequacy checking, Tukey's test of additivity, Duncan's multiple range test.

ModuleII

Completely randomized designs, randomized block designs, latin square design, Graeco latin square design, Analysis with missing values in CRD, RBD and LSD, Analysis of Covariance.

Module III

Incomplete block designs, Balanced incomplete block designs, recovering intra block and inter block information in BIBD, construction of BIBD, PBIBD, Analysis of PBIBD with two associate classes. Lattice designs.

Module IV

Factorial experiments: Testing of significance of factorial effects of 2^2,2^3 and 3^2 experiments, Yates procedure for estimating the effects. Complete confounding, partial confounding. Split plot designs. Concept of split-split plot and strip plot designs.

Text Books:

1. Das, M.N. and Giri, N. (1979). Design and Analysis of Experiments.
2. Montgomery, C.J. (1976). Design and Analysis of Experiments, Wiley Eastern.
3. Joshi, D.D. (1987). Linear Estimation and Design and Analysis of Experiments,Wiley Eastern.
4. Dean, A. and Voss, D. (2006). Design and Analysis of Experiments, Springer.

References:

1. Chakravarthi, M.C. (1962). Mathematics of Design and Analysis of Experiments, Asia Publishing House, Bombay.
2. Hinkelmann, K., Kempthorne, O.(2007). Design and Analysis of Experiments, Volume 1: Introduction to Experimental Design, 2nd Edition, Wiley.
3. Hinkelmann, K., Kempthorne, O.(2005). Design and Analysis of Experiments, Volume 2: Advanced Experimental Design, Wiley.

COURSE CODE: ST 242
COURSE TITLE: STOCHASTIC PROCESSES

COURSE OUTCOMES

On completion of the course, students should be able to:

CO1. Describe and exemplify concepts of Stochastic processes, time space and state space, classification of stochastic processes based on the nature of time space and state space, Classical stochastic processes like processes with stationary independent increments, Markov process, martingales, Wiener process, Gaussian process

CO2. Distinguish between strict and weak (covariance or wide sense) stationarity,

CO3. Explain Markov chains: Definition, transition probability matrix, n-step transition Probability and Chapman-Kolmogorov equation, Calculate n-step transition probabilities, Classify states of a finite Markov chain .

CO4. Describe periodicity and ergodicity of chains, Describe limiting behavior of n-step transition probabilities, obtain the stationary distribution of a Markov chain

CO5. Explain and exemplify continuous time Markov chain, Poisson process, pure birth process, birth and death processes, compound Poisson process, Markov Process with discrete states.

CO6. Explain and exemplify renewal processes, renewal equation. Describe and apply renewal theorem.

CO7. Describe Branching processes, offspring distribution, extinction probabilities

MODULE OUTCOMES

SL. NO	**Outcomes** On completion of each module, students should be able to:	Taxonomy Level
Module I.	M01. Articulate and exemplify the concepts of Stochastic processes, time space and state space. M02. Construction of examples of Stochastic processes M03. Explain the concepts of particular types of stochastic processes like process with stationary independent increments, Markov process, martingales, Wiener process, Gaussian process etc.	Understand Understand Apply
Module II	M01. Articulate concepts of Markov chains, transition probability matrix, n-step transition probabilities M02. Calculate n-step transition probabilities M03. Describe and exemplify classification of states in a Markov Chain M04. Calculate the periodicity of a Markov Chain M05. Explain the concepts of recurrence, ergodic chains M06.Explain and exemplify concepts of limiting behaviour of n-step transition probabilities. M07. Describe stationary distributions and solve problems	Understand Evaluation Understand Evaluation Understand Understand Apply
Module III	M01. Describe and exemplify: Continuous time Markov chains, Poisson process, pure birth process, birth and death processes. M02. Derive of steady state probabilities/differential difference equations in case of Poisson process, pure birth process, birth and death processes. M03. Describe and exemplify: Compound Poisson process, M04 Derive properties of Poisson process and Compound Poisson process M05. Explain the concept of Markov Process with discrete states. M06. Illustrate these processes with examples	Understand Evaluation Understand Evaluation Understand Apply
Module IV.	M01. Describe and exemplify: renewal processes,	Understand

	renewal equation.	
	M02. Explain the statement and applications of renewal theorem	Apply
	M03. Solve problems based on the applications of renewal theorem	Apply
	M04. Concepts of stopping time, Wald's equation, residual and excess life times, backward and forward recurrence times,	Understand
	M05. Poisson process as a renewal process	Analyse
	M06. Describe and exemplify Galton-Watson branching processes	Understand
	M07. Explain concepts of offspring distribution and its implications	Apply
	M08. Interpret the concept of extinction probabilities	Apply
	M09. Compute the probability extinction in case of a particular offspring distribution.	Evaluation

COURSE CONTENT

Module I

Introduction to stochastic processes - time and state space, classification of stochastic processes, processes with independent increments, Stationary processes-definition and examples, Gaussian process, Martingales, Markov process, random walk and Wiener process (examples).

Module II

Markov chain, transition probabilities and stationary transition probabilities, transition probability matrix, Chapman - Kolmogorov equation: classification of states, first passage time distribution, stationary distribution, irreducible Markov chain, aperiodic chain, ergodic theorem and Gamblers ruin problem.

Module III

Poisson process - Properties of Poisson process and related distributions, compound Poisson process, pure birth process, birth immigration process, time dependent Poisson process, pure death process and birth and death process.

Module IV

Renewal process - definition and examples, renewal function and renewal density, renewal equation, statement and applications of renewal theorems, stopping time, Wald's equation, residual and excess life times, backward and forward recurrence times, Poisson process as a renewal process, branching process - definitions and examples, generating function of branching process, Galton - Watson branching process, probability of ultimate extinction, distribution of total number of progeny.

Text books:

1. Karlin, S. and Taylor, H.M. (1975). A First Course in Stochastic Processes, Academic Press.
2. Medhi, J. (2009). Stochastic Processes, New Age International Publishers, New Delhi.
3. Box, G.E.P., Jenkins G.M. and Reinsel, G.C. (2007) Time Series Analysis, Forecasting and Control, Pearson Education.
4. Brockwell,P J. and David R. A. (2002). Introduction to time series and forecasting, 2nd edition, Springer.

References:

1. Bhat, U.N. (1972). Elements of Applied Stochastic Processes, John Wiley, New York
2. Cinlar, E. (1975). Introduction to Stochastic Processes, Prentice Hall, Inc, New York.
3. Makridakis, S and Wheelwright, S C. Forecasting methods and applications, John Wiley and Sons
4. Feller, W. (1968). Introduction to Probability Theory and Applications, Vol. I, John Wiley, New York
5. Feller, W. (1971). Introduction to Probability Theory and Applications, Vol. II, John Wiley, New York

COURSE CODE : 243
COURSE TITLE : REGRESSION METHODS

COURSE OUTCOMES

On completion of the course, students should be able to:

CO1: Describe simple and multiple linear regression models and its assumptions.

CO2: Apply principle of least square method to estimate the parameters in simple and multiple linear regression models.

CO3: Identify multi collinearity problem and its consequences.

CO4: Describe generalized least square method of estimation.

CO5: Understand Residual Analysis and residual plots.

CO6: Explain Generalized Linear models and inference on models with binary response.

CO7: Describe log-linear models for categorical variables.

Module Outcomes

Sl.No	Outcomes On completion of each module, students should be able to	Taxonomy level
Module 1	MO1. Explain simple linear regression model MO2. Describe least square estimators MO3. Articulate to inference regarding regression parameters MO4. Meaning of coefficient of determination.	Understand Remember Apply Analysis
Module II	MO1. Explain multiple linear regression models MO2. Explain inference regarding multiple regression parameters MO3.Methods of Generalized and weighted least squares.	Analysis Understand Apply
Module III	MO1. Different methods of scaling residuals MO2. Residual plots MO3: Detecton of Outliers. MO4. Explain Polynomial regression models MO5. Explain Indicator variables and its usage. MO5. Describe model building strategy MO6: Concept of Stepwise Regressiom. MO7: Problem of multicollinearity	Understand Analysis Understand Understand Understand Apply Apply Understand
Module IV	MO1. Explain Generalized Linear models MO2. Explain models with binary resonse. MO3. Describe link functions MO4: Inference on Poisson regression MO5: Log linear models for categorical data.	Understand Understand Apply Apply Analysis

Course Content

Module I

Identification of Variables, Models, Regression models. Fitting of models- Principle of Least squares, Inference on simple linear regression models. Properties of least square estimators. Significance test and confidence intervals, prediction problems. Coefficient of determination.

Module II

Multiple linear regression models, least square estimation, Properties of least square estimators, hypothesis testing on regression parameters, ANOVA, confidence estimation, prediction of new observations, Generalized and Weighted least squares.

Module III

Residual analysis- Methods of scaling residuals, Residual plots, Partial residual plots, PRESS Statistic.

Polynomial regression, estimation and inference on structural parameters, Indicator variables, uses of Indicator variables, variable selection and model building strategy, All possible regressions, Stepwise regression, Problem of multicollinearity- meaning, sources and consequences.

Module IV

Generalized Linear models, contingency tables, binary response variables- logit models, Log linear models, Logistic regression, Estimation and testing the models, link functions, Poisson regression and its inference.

Logit models for categorical data, Goodness of fit, log linear models for categorical variables (two way contingency table)

Dose response models- quartile response, probit models and median lethal dose.

Text Books:

1. Montgomery, D.C. , Peck, E.A. and Vining, G.G. (2003). Introduction to Linear Regression Analysis, John Wiley & Sons, Asia
2. Rao, C, R. and Tutenburg, H. (1995). Linear Models , Springer Series in Statistics, New York
3. Dobson, A.J. (2002) An Introduction to Generalized Linear models, Second edition, CRC Press.

References:

1. Mc Cullagh, P. and Nelder, J.A. (1989). Generalized Linear Models, Chapman and Hall.
2. Neter, J. and Wasserman, D.W. (1983). Applied Linear Statistical Models, Richard, D. Irwin, Inc., Illinois.
3. Rao, C.R. (1973). Linear Statistical Inference and its Applications, Wiley, New York.
4. Draper, N.R. and Smith, R. (2003). Applied Regression Analysis, John Wiley and Sons inc., New York
5. Seber, G.A.F. (1977). Linear Regression Analysis, John Wiley and Sons, New York

COURSE TITLE: ST 244
COURSE TITLE : Elective II- (i) TIME SERIES ANALYSIS AND FORECASTING

Course Outcomes

On completion of the course, students should be able to:

CO1. Identify, analyze and predict an appropriate model for a given time series data.

CO2. Identify trends, cycles, and seasonal variances and aid in the forecasting of a future event.

CO3. Distinguish between stationary, non stationary time series and other time series models.

CO4. Explain and exemplify the changes associated with the chosen data point compare to shifts in other variables
over the same **time** period.

CO5. Predict future observations and / or estimate unobservable components like trend and seasonal effects.

MODULE OUTCOMES

SL. NO	**Outcomes** On completion of each module, students should be able to:	**Taxonomy Level**
Module I.	M01. Articulate and exemplify the concepts of time series. M02. Construction of examples of various time series data based on trend, seasonality M03. Explain the concepts of additive and multiplicative models, estimation and elimination of the trend and seasonality, exponential and moving average smoothing, holt-winter smoothing, forecasting based on smoothing M04 Analyze the series and detect the presence of the trend and seasonal variation, hence eliminate the presence of the said factors using appropriate methods	Remember and Understand Create Understand Analyze

Module II.	M01. Explain the Stationary time series, Autocorrelation, partial auto correlation function M02. Develop Linear stationary models: auto regressive, moving average and mixed processes. M03.Apply Linear non-stationary models- Autoregressive integrated moving average (ARIMA) models to time series data. M04. Estimate the parameters and forecaste the time series data in the case of ARMA and ARIMA models	Understand Create Understand Apply and Analyze
Module III.	M01.Describe and exemplify the methods of estimation of parameters of the ARMA and ARIMA models. M02. Identify the presence of autocorrelation. M03. Identify and Fit an Auto regressive Process or a Moving Average Process appropriately for a time series data. M04. Estimate the parameters and forecast the time series data in the case of ARMA and ARIMA models.	Remember and Understand Understand Apply Apply and Analyze

Module IV.	M01. Recollect and provide examples for non stationary time series, and seasonal time series models, state space models, ARCH and GARCH models	Remember and Understand Analyze Evaluate and Analyze

COURSE CONTENT

MODULE I

Time series, examples and objectives of time series analysis, components of time series, additive and multiplicative models, determination of trend, analysis of seasonal fluctuations, test for trend and seasonality, exponential and moving average smoothing, holt-winter smoothing, forecasting based on smoothing.

MODULE II

Stationary Processes, Some Useful Models, Detailed study of the stationary processes: moving average (MA), autoregressive (AR), Autoregressive Moving Average (ARMA) models and Autoregressive Integrated Moving Average (ARIMA) models.

MODULE III

Estimation of Auto covariance and auto correlation functions, Estimation of parameters of an ARMA model, Estimation of parameters of an ARIMA Model, choice of AR and MA periods, forecasting, residual analysis and diagnostic checking. Regression with ARMA Errors- OLS and GLS Estimation, ML Estimation. Forecasting ARMA and ARIMA models.

MODULE IV

Basic concepts and examples of non stationary and seasonal time series models, state space models, ARCH and GARCH models.

Text Books

1. Brockwell, P. J., & Davis, R. A. (2016). *Introduction to time series and forecasting*. Springer.
2. Chatfield, C. (2009). *The analysis of time series an introduction*. Chapman and Hall/CRC (Sixth Special Indian Edition).
3. Chatfield, C. (2013). *The analysis of time series: theory and practice*. Springer.
4. Montgomery, D. C., Jennings, C. L., &Kulahci, M. (2015). *Introduction to time series analysis and forecasting*. John Wiley & Sons.

Reference

1. Abraham, B., &Ledolter, J. (2009). *Statistical methods for forecasting* (Vol. 234). John Wiley & Sons.
2. Box, G. E., Jenkins, G. M., Reinsel, G. C., &Ljung, G. M. (2015). *Time series analysis: forecasting and control*. John Wiley & Sons.
3. Brockwell, P. J., Davis, R. A., & Fienberg, S. E. (1991). *Time series: theory and methods: theory and methods*. Springer Science & Business Media.
4. Chatfield, C., & Xing, H. (2019). *The analysis of time series: an introduction with R*. CRC press.
5. Cryer, J. D., & Chan, K. S. (2008). *Time series analysis: with applications in R*. Springer Science & Business Media.
6. Jonathan, D. C., & Kung-Sik, C. (2008). Time series analysis with applications in R. *SpringerLink, Springer eBooks*.
7. Faouzi, J., &Janati, H. (2020). pyts: A Python Package for Time Series Classification. *Journal of Machine Learning Research*, *21*(46), 1-6.
8. McKinney, W., Perktold, J., &Seabold, S. (2011). Time series analysis in Python with statsmodels. *Jarrodmillman Com*, 96-102.
9. Ostrom, C. W. (1990). *Time series analysis: Regression techniques* (No. 9). Sage.
10. Pal, A., & Prakash, P. K. S. (2017). *Practical time series analysis: master time series data processing, visualization, and modeling using python*. Packt Publishing Ltd.
11. Prado, R., & West, M. (2010). *Time series: modeling, computation, and inference*. CRC Press.

12. Seabold, S., &Perktold, J. (2010, June). Statsmodels: Econometric and statistical modeling with python. In *Proceedings of the 9th Python in Science Conference* (Vol. 57, p. 61).
13. Yaffee, R. A., & McGee, M. (2000). *An introduction to time series analysis and forecasting: with applications of SAS® and SPSS®*. Elsevier.
14. Wei, W. W. (2018). *Multivariate time series analysis and applications*. John Wiley & Sons.

COURSE TITLE: ST 244
COURSE TITLE : Elective II- (ii) BAYESIAN INFERENCE

COURSE OUTCOMES
On completion of the course, students should be able to:
CO1. Use relative frequencies to estimate probabilities.
CO2. Calculate conditional probabilities
CO3. Calculate posterior probabilities using Bayes' theorem.
CO4. Calculate simple likelihood functions

MODULE OUTCOMES

MODULE	**Module outcomes** *On completion of each module, students should be able to:*	**Taxonomy Level**
MODULE 1	M01. Explain prior distribution M02.Interpret Bayes theorem and articulate to find posterior distribution.checking	Understand Apply
MODULE 1I	M01. Find conjugate family of prior for a model M02. Choose appropriate member of conjugate prior for a family MO3. Explain non-informative, improper and invariant priors MO4. Define Jeffrey's invariant prior	Analysis Analysis Apply Understand
MODULE III	MO1. Explain different types of loss function. MO2. Evaluate the estimate in terms of posterior risk	Apply Apply
MODULE IV	MO1. Explain Bayesian interval estimation MO2. Explain highest posterior density regions MO3. Interpret confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval	Analysis Apply Evaluate Understand

COURSE CONTENT

MODULE I: Subjective interpretation of probability in terms of fair odds. Evaluation of (i) subjective probability of an event using a subjectively unbiased coin (ii) subjective prior distribution of a parameter. Bayes theorem and computation of the posterior distribution.

MODULE II: Natural Conjugate family of priors for a model. Hyper parameters of a prior from conjugate family. Conjugate families for (i) exponential family models, (ii) models admitting sufficient statistics of fixed dimension. Enlarging the natural conjugate family by (i) enlarging hyper parameter space (ii) mixtures from conjugate family, choosing an appropriate member of conjugate prior family. Non-informative, improper and invariant priors. Jeffrey's invariant prior.

MODULE III: Bayesian point estimation: as a prediction problem from posterior distribution. Bayes estimators for (i) absolute error loss (ii) squared error loss (iii) 0 - 1 loss. Generalization to convex loss functions. Evaluation of the estimate in terms of the posterior risk.

MODULE IV: Bayesian interval estimation: Credible intervals. Highest posterior density regions. Interpretation of the confidence coefficient of an interval and its comparison with the interpretation of the confidence coefficient for a classical confidence interval.

REFERENCES

Berger, J. O. (1980): Statistical Decision Theory and Bayesian Analysis, Springer Verlag.

Bernando, J. M. and Smith, A. F. M. (1994): Bayesian Theory, Jolm Wiley and Sons.

DeGroot, M. H. (1970): Optimal Statistical Decisions, McGraw Hill.

Gemerman, D. (1997): Markov Chain Monte Carlo Stochastic Simulation for Bayesian Inference, Chapman Hall.

Leonard, T. and Hsu, J. S. J. (1999): Bayesian Methods, Cambridge University Press.

Robert, C. P. (1994): The Bayesian Choice: A decision Theoretic Motivation, Springer.

COURSE TITLE: ST 244
COURSE TITLE : Elective II- (iii) ACTUARIAL STATISTICS

COURSE OUTCOMES

On completion of the course, students should be able to:

CO1. Develop a greater understanding of statistical principles and their application in actuarial statistics.

CO2. Describe the core areas of actuarial practice and relate to those areas actuarial principles, theories and models.

CO3. Describe estimation procedures for lifetime distributions. CO4 Explain the concept of survival models.

CO5. Understand the application of knowledge of the life insurance environment.

CO6. Describe Net premiums and its various types.

CO7. Expand their applied knowledge in various specialized areas of actuarial studies and statistics.

MODULE OUTCOMES

Sl. No:	**Outcomes** On completion of each module, students should be able to:	**Taxonomy level**

MODULE 1	MO1. Explains the utility theory and insurance. MO2. Explain survival function and application. MO3. Examine the properties of force of mortality. MO4 Define Life tables and its relation with rvival function, examples. MO5.Explain Multiple life functions and its properties. MO6. Articulate the insurance and annuity benefits through multiple life functions evaluation for special mortality laws. MO7. Explains the Multiple decrement tables. MO8.Describe net single premiums and their numerical Evaluations	Understand Understand Apply Remember Understand Analysis Understand Remember
MODULE II	MO1.Define Distribution of aggregate claims . MO2. Derive the compound Poisson distribution and explain its applications. MO3. Explain Principles of compound interest and its attributes.	Understand Remember Understand
MODULE III	MO1. Explain the Life insurance and its types. MO2 : Describe Insurance payable at the moment of death and at the end of the year of death-level benefit insurance MO3. Explain the Life annuities and its types.	Understand Analysis Understand
MODULE IV	MO1. Explain Net premiums and its importance MO2. Distinguish between Continuous and discrete premiums MO3. Accumulation type benefits.	Understand Analysis Apply

COURSE CONTENT

MODULE I

Utility theory, insurance and utility theory, models for individual claims and theirnsums, survival function, curtate future lifetime, force of mortality. Life tables and its

relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement tables, central rates of multiples decrement, net single premiums and their numerical evaluations.

MODULE II

Distribution of aggregate claims, compound Poisson distribution and its applications. Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

MODULE III

Life insurance: Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, differed insurance and varying benefit insurance, recursions, commutation functions. Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities immediate and apportion able annuities-due.

MODULE IV

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportion able premiums, commutation functions, accumulation type benefits. payment premiums, apportion able premiums, commutation functions, accumulation type benefits.

TEXT BOOKS

1. Beard, R.E., Penlikainen, T. and Pesonnen, E (1984): Risk Theory: The Stochastic Basis of Insurance, 3rd Edition, Chapman and Hall, Londan.
2. Bowers, N.L., Gerber, H.U., Hickman, J.E., Jones, D.A. and Nesbitt, C.J. (1997): ' Actuarial Mathematics', Society of Actuarias, Ithaca, Illiois, U.S.A., second Edition.
3. Neill, A. (1977): Life Contingencies, Heineman.

COURSE CODE: ST 245
COURSE TITLE: PRACTICAL II USING R

Topics cover ST 233, ST 241, ST 243 and ST 244.