Rayat Shikshan Sanstha's

Yashavantrao Chavan Institute of Science, Satara
(Autonomous)

Post-graduate Programme

M. Sc. in Statistics

Syllabi of the course

Choice based credit system syllabus

(To be implemented from academic year 2021-22)

Preamble

The goal of syllabus to make the study of Statistics popular and interesting among the students for job achievements as well as higher studies.

The syllabus is prepared after discussion at length with number of faculty members of the subject and experts from industries and research fields. The units of the syllabus are well defined, taking into consideration the level and capacity of students.

Eligibility: B. Sc. with Statistics as principal subject.

General Objectives of the Course:

1. The students are expected to understand the principles, concepts and recent developments in the Statistics.
2. To enhance student sense of enthusiasm for Statistics and to involve them in an intellectually stimulating experience of learning in a supportive environment.
3. The practical course is framed in relevance with the theory courses to improve the understanding of the various concepts in Statistics.

Program Outcomes (PO):

On successful completion of the program students will able to:

PO1: Understand the principles and concepts in the statistical theory at an advanced level which take into account recent advances in the subject.

PO2: Acquire the strong foundation of statistical concepts which will benefit them to become good academicians.

PO3: Use acquired statistical methodologies and modeling techniques to address real-life problems.

PO4: Gain the knowledge of software which has the wide range of opportunities in the Quality control, Planning and development, IT sector, R&D in industries, Business, Government and private sector etc.

PO5: Qualify various National / State level competitive exams like ISS, DSO, CSIR-UGC NET, SET, GATE, MPSC, UPSC, Banking etc.

Program Specific Outcomes (PSO):

On successful completion of the program students will able to:

PSO1: Enhance sense of enthusiasm for Statistics and to involve them in an intellectually stimulating experience of learning in a supportive environment.

PSO2: Handle and analyse small as well as large databases with computer skills.

PSO3: Understand, implement and develop statistical models.

PSO4: Describe complex statistical ideas to non-statisticians and to present the results of their analyses in written, oral forms and can make practical suggestions for improvement.

PSO5: The project work and presentation may enable to take prominent roles in a wide spectrum of employment and research.

Other features:

1. **Library:**

Reference and Textbooks, Journals and Periodicals, Reference Books for Advanced Books for Advanced studies.

2. **Specific equipment's in laboratory:**

60 Computers, LCD Projector, Visualizer, Smart board etc.

61 Laboratory Software's:

1. SAS	2. SPSS	3. R-Software.
4. MINITAB	5. Python	

1. **Title:** M. Sc.(Statistics)

2. **Year of Implementation:** The syllabus will be implemented from June, 2021-22 onwards.

3. **Duration:** Two Years

4. **Pattern:** M. Sc. Statistics program has semester pattern and Choice Based Credit System. The program consists of 96credits.

5. **Medium of instruction:** English

6. **Structure of course:**

Notations:

A six-character code is given to each paper. In MST "M" stands for M.Sc., "S" stands for Statistics, "T" stands for Theory and "P" stands for practical. The first digit following MST is Semester Number. The second digit "0" stands for the core theory course, the digit "1" stands for a practical paper and the third digit indicates the serial number of paper in that semester.

M.Sc. Part-I

Semester – I

Course Code	Title of the course	Instruction Hrs/week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
MST 101	Real Analysis	4	60	40	4
MST 102	Linear Algebra	4	60	40	4
MST 103	Population Studies	4	60	40	4
MST 104	Estimation Theory	4	60	40	4
MST 105	Optimization Technique - I	4	60	40	4
MSP116	Practical-I	12	60	40	4
Total Credits of Sem-I					**24**

M.Sc. (Statistics) Semester – II

Course Code	Title of the course	Instruction Hrs/week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
MST 201	Probability Theory	4	60	40	4
MST 202	Theory of Testing of Hypotheses	4	60	40	4
MST 203	Regression Analysis	4	60	40	4
MST 204	Linear Model and Design of Experiment	4	60	40	4
MST 205	Sampling Theory	4	60	40	4
MSP 216	Practical-II	12	60	40	4
Total Credits of Sem-II					**24**

Equivalence

Semester I

Old		New	
Course Code	**Title of the course**	**Course Code**	**Title of the course**
MST 101	Real Analysis	MST 101	Real Analysis
MST 102	Linear Algebra	MST 102	Linear Algebra
MST 103	Distribution Theory	MST 103	Population Studies
MST 104	Estimation Theory	MST 104	Estimation Theory
MST 105	Optimization Technique - I	MST 105	Optimization Technique - I
MSP 116	Practical-I	MSP 116	Practical-I

Semester II

Old		New	
Course Code	**Title of the course**	**Course Code**	**Title of the course**
MST 201	Probability Theory	MST 201	Probability Theory
MST 202	Theory of Testing of Hypotheses	MST 202	Theory of Testing of Hypotheses
MST 203	Multivariate Analysis	MST 203	Regression Analysis
MST 204	Linear Model and Design of Experiment	MST 204	Linear Model and Design of Experiment
MST 205	Sampling Theory	MST 205	Sampling Theory
MSP 216	Practical-II	MSP 216	Practical-II

M. Sc. Part II

M.Sc. (Statistics) Semester – III

Course Code	Title of the course	Instruction Hrs./week	Marks- End Semester Exam	Marks- Internal Assessment	Credits
MST 301	Asymptotic Inference	4	80	20	4
MST 302	Survival Analysis	4	80	20	4
MST 303	Multivariate Analysis	4	80	20	4
MST 304	Data Mining	4	80	20	4
MST 305	Clinical Trials	4	80	20	4
MSP 316	Practical III	12	80	20	4
Total Credits Sem-III					**24**

M.Sc. (Statistics) Semester – IV

Course Code	Title of the Course	Instruction Hrs./week	Marks End Semester Exam (ESE)	Marks Internal Assessment (ISE)	Credits
MST 401	Optimization Techniques –II	4	80	20	4
MST 402	Elementary Stochastic Processes	4	80	20	4
MST 403	Time Series Analysis	4	80	20	4
MST 404	Planning and Analysis of Industrial Experiments	4	80	20	4
MST 405	Actuarial Statistics	4	80	20	4
MSP 416	Practical-IV	12	80	20	4
Total Credits Sem-IV					**24**

Equivalence

Semester III

OLD		NEW	
Course Code	**Title of the course**	**Course Code**	**Title of the course**
MST 301	Asymptotic Inference	MST 301	Asymptotic Inference
MST 302	Survival Analysis	MST 302	Survival Analysis
MST 303	Regression Analysis	MST 303	**Multivariate Analysis**
MST 304	Data Mining	MST 304	Data Mining
MST 305	Clinical Trials	MST 305	Clinical Trials
MSP 316	Practical III	MSP 316	Practical III

Semester IV

OLD		NEW	
Course Code	**Title of the course**	**Course Code**	**Title of the course**
MST 401	Optimization Techniques –II	MST 401	Optimization Techniques –II
MST 402	Elementary Stochastic Processes	MST 402	Elementary Stochastic Processes
MST 403	Time Series Analysis	MST 403	Time Series Analysis
MST 404	Planning and Analysis of Industrial Experiments	MST 404	Planning and Analysis of Industrial Experiments
MST 405	Actuarial Statistics	MST 405	Actuarial Statistics
MSP 416	Practical-IV	MSP 416	Practical-IV

Syllabus:

MST 301: ASYMPTOTIC INFERENCE

Course Objective: Student will able to

1. Uunderstand the basic idea of consistency of an estimator.
2. Develop generalization aspect of inferential theory.
3. Learn the methods of constructing consistent estimators, Method of Moments.
4. Study the theories and methods of asymptotic inference.

Credits=4	**SEMESTER-III** **MST 301: ASYMPTOTIC INFERENCE**	**No. of hours per unit / credits**
Credit –1 **UNIT I**	Review of Consistency of an estimator, weak and strong consistency, joint and marginal consistency, invariance property under continuous transformations, methods of constructing consistent estimators, asymptotic relative efficiency. Consistent and Asymptotic Normal (CAN) Estimators: Definition of CAN estimator for real and vector valued parameters, invariance of CAN property under non-vanishing differentiable transformation. Methods of constructing CAN estimators: Method of Moments, method of percentiles, comparison of CAN estimators.	**(15)**
Credit –1 **UNIT II**	BAN estimators, CAN and BAN estimators in one parameter and multi-parameter exponential family of distributions, super-efficient estimators, Crammer regularity conditions, Cramer – Huzurbazar results. Sheffe's theorem, Polya's theorem and Slutsky's theorem.	**(15)**
Credit –1 **UNIT III**	Variance stabilizing transformations; their existence; their applications in obtaining large sample tests and estimators. Asymptotic Confidence Intervals based on CAN estimators and based on VST, Asymptotic distribution of function of sample moments. Asymptotic Confidence regions in multi-parameter families. Gauss-Legendre-Boscovich Revisited, unbiased confidence intervals.	**(15)**
Credit –1 **UNIT IV**	Likelihood ratio test and its asymptotic distribution, Wald test, Rao's Score test, Pearson Chi- square test for goodness of fit, Bartlett's test for homogeneity of variances, Levens test . Consistent test, comparison of tests: asymptotic relative efficiency of tests (Pitman and Bahadur efficiency).	**(15)**

Course Outcomes: Students should able to

1. Distinguish between weak and strong consistency , joint and marginal consistency
2. Uunderstand the concept of CAN and BAN estimators, their related results.
3. Uunderstand the concept of super-efficient estimator, variance stabilizing transformation and their application in large sample test.
4. Obtain the asymptotic confidence interval based on CAN and VST.

BOOKS RECOMMENDED:

1. Kale B.K., A first course on parametric inference (Narosa Pub., 1999)
2. S. Zacks Wiley & Sons inc., Theory of statistical inference (Wiley, 1971)

3. V. K. Rohatagi and A. K. Md. E. Saleh, Introduction to Probability Theory and Mathematical Statistics (John Wiley and sons Inc., 2001)
4. T.S. Ferguson, A Course in Large Sample Theory (Chapman and Hall, 1996)
5. E. L. Lehmann, Elements of Large Sample Theory (Springer, 1999)
6. Das Gupta A., Asymptotic Theory of Statistics and Probability (Springer Texts in Statistics., 2008)
7. Manoj Kumar Srivastava, Abdul Hamid Khan, Namita Srivastava, Statistical Inference (PHI learning pvt. Ltd, 2014)

MST 302: SURVIVAL ANALYSES

Course Objective: Student will able to

1. Provide students the ability to sharpen the skills necessary to collect, handle and analyse the lifetime data.
2. Learn the reliability theory and analysis of survival data.
3. Distinguish censored and uncensored data.
4. Visualize and communicate time-to-event data, to fit and interpret failure time model.

Credits=4	**MST 302: SURVIVAL ANALYSES**	**No. of hours per unit / credits**
Credit –1 UNIT I	**Estimating the survivor function:** Various types of censoring: right, left, interval Censoring; random censoring; Survivor, hazard and cumulative hazard functions. Estimating the survivor function: Life-table estimate, Kaplan-Meier estimate, Nelson-Aalen estimate; Standard error of the estimated survivor functions; Confidence intervals for values of the survivor function; Estimating the hazard function; Estimating the cumulative hazard function; Estimating the median and percentiles of survival times; Confidence intervals for the median and percentiles.	**(15)**
Credit –1 UNIT II	**The Cox regression model:** A regression model for the comparison of two groups; The general proportional hazards model, Models corresponding to the linear component of the model: including a variate, a factor, an interaction, a mixed term. Fitting the Cox regression model in R, Likelihood function for the model, Treatment of ties, Confidence intervals and hypothesis tests for coefficients and for hazard ratios using R; Measures of explained variation, Measures of predictive ability, Model checking using various types of residuals: Cox-Snell; Modified CoxSnell; Martingale; Deviance; Schoenfeld; Score residuals, plots based on these residuals and their interpretation.	**(15)**
Credit –1 UNIT III	**Competing risks:** Summarising competing risks data; Kaplan-Meier estimate of survivor function; its properties without proof, Hazard and cumulative incidence functions; Cause specific hazard function; Cause-specific cumulative incidence function; Likelihood functions for competing risks models; Parametric models for cumulative incidence functions.	**(15)**
Credit –1 UNIT IV	a) Comparison of two groups of survival data: The log-rank test; The Wilcoxon test; Comparison of three or more groups of survival data. b) Introduction to frailty Models: Random effects, Individual frailty, Shared frailty; Frailty distributions: The gamma frailty distribution; Lognormal frailty effects; Testing for the presence of frailty; The shared	**(15)**

	frailty model; Fitting the shared frailty model; Comparing shared frailty models.	

Course Outcomes: Students should able to

1. Collect the life time data using different methods of censoring.
2. Apply the Cox regression model
3. Understand concept of competing risk analysis and how to apply in real life situations.
4. Use regression methods for life time data.

BOOKS RECOMMENDED:

1. R. E. Barlow & F. Proschann, Mathematical Theory of Reliability (John Wiley & Sons, Inc.,1965)
2. J. V. Deshpande and S.G. Purohit Life Time Data: Statistical Models and Methods (World scientific publishing, 2005)
3. J. F. Lawless, Statistical Models and Methods of Failure Time Data (John Wiley.,1982)
4. R. G. Miller, Survival Analysis (John Wiley and Sons., 1981)
5. L. O. Bain, Statistical Analysis of Reliability and Life Testing Models (Marcel Dekker,1978)
6. W. Nelson, Applied Life Data Analysis (Jhon Wiley and Sons Inc.,1982)
7. J. Medhi, Stochastic Processes, Second edition (New Age Science Ltd., 1994)

MST 203: MULTIVARIATE ANALYSIS

Course Objectives: Student will able to

1. Learn and develop scientific view to deal with multidimensional datasets and its uses in the analysis of research data.
2. Understand the extensions of univariate techniques to multivariate frameworks.
3. Apply dimension reduction techniques used for data analysis.
4. Construct group of similar objects with respect to some characters by hierarchical and non-hierarchical way.

Credits=4	**MST 203: MULTIVARIATE ANALYSIS**	**No. of hours per unit / credits**
Credit –1 UNIT I	Exploratory multivariate data analysis, sample mean vector, sample dispersion matrix, correlation matrix, graphical representation, means, variances, covariances, Partial and multiple correlation coefficients. Correlations of linear transforms. Multivariate normal distribution, two definitions and their equivalence, singular and nonsingular normal distribution, characteristic function, moments, marginal and conditional distributions.	**(15)**
Credit –1 UNIT II	Maximum likelihood estimators of the parameters of the multivariate normal distribution and their sampling distributions. Hotelling's T^2 Statistic and its null distribution. Applications of T^2 statistics and its relationship with Mahalanobis' D^2 statistic. Goodness of fit of multivariate normal distribution, Confidence region for the mean vector, Tests of significance for multiple and partial correlation coefficients. Wishart matrix and its distribution, properties of Wishart distribution, distribution of generalized variance.	**(15)**
Credit –1	Discrimination and classification. Fisher's discriminant function and likelihood ratio procedure, minimum ECM rule, Rao's U statistics and its use in tests associated with	**(15)**

UNIT III	discriminant function, classification with three populations. Cluster analysis, Heirarchical methods: Single, Complete, average linkage method and non- hierarchical clustering method-k- means clustering.	
Credit –1 UNIT IV	Canonical correlation analysis, Introduction to principal component analysis and related results, Introduction to factor analysis and estimation: PCA, MLE Method, Methods of Rotation, Factors Score.	**(15)**

Course Outcomes: Students should able to

1. Understand multivariate normal distribution and their real life applications.
2. Understand Wishart distribution, Hotelling T2 and Mahalanobis D2 statistic.
3. Implement dimension reduction techniques using software on real life problems.
4. Demonstrate knowledge of the basic ideas behind discriminant and clustering analysis techniques with applications.

BOOKS RECOMMENDED:

1. Kshirsagar A.M., Multivariate Analysis (Marcel- Dekker, 1972).
2. Johnson, R. A. and Wichern. D.W, Applied Multivariate Analysis **(**lysis. Prentice–Hall, 5th Ed. 2002)
3. Anderson T. W., An Introduction to Multivariate Statistical Analysis (John Wiely, 2nd Ed.1984).
4. Morrison D. F., Multivariate Statistical Methods (Mc Graw-Hill, 1976).

MST 304: DATA MINING

Course Objectives: Student will able to

1. The course aims to develop the skills necessary to handle and analyse the big and complex data to solve the problems.
2. The concept of data mining for enterprise data management and as a cutting edge technology tool.
3. Enable to identify data sources, processing and imparting knowledge tools to analyze sets of data to gain useful business understanding.
4. Understand unsupervised learning and supervised learning techniques for univariate and multivariate data.

Credits=4	**MST 304: DATA MINING**	**No. of hours per unit / credits**
Credit –1 UNIT I	Data understanding and data cleaning, concept of supervised and unsupervised learning. Problem of classification, classification techniques: k-nearest neighbor, decision tree, Naïve Bayesian, classification based on logistic regression, Bayesian belief Network., CART (classification and regression trees) L1 and L2 Regularization, Discriminant Classification.	**(15)**
Credit –1 UNIT II	Model evaluation and selection: Metrics for Evaluating Classifier Performance, Holdout Method and Random Subsampling, Cross-Validation, Bootstrap, Model Selection Using Statistical Tests of Significance, Comparing Classifiers Based on Cost–Benefit and ROC Curves. Techniques to Improve Classification Accuracy: Introduction to Ensemble Methods, Bagging, Boosting and Ada Boost, Random Forests, Improving Classification Accuracy of Class-Imbalanced Data.	**(15)**
Credit –1 UNIT III	ANN and SVM: Artificial Neutral Network (ANN): Introduction to ANN, types of activation function, McCulloch-Pitts AN model, single layer network, multilayer feed forward network model, training methods, ANN & regression models. Convexity and	**(15)**

	optimization: Convexity, unconstrained and constrained optimization, KKT conditions. Deep Learning, Learning a Deep Network. Support vector machine: Introduction to support vector machine, loss functions, soft margin, optimization hyperplane, support vector classification, support vector regression, linear programming support vector machine for classification and regression.	
Credit –1 UNIT IV	Unsupervised learning: Clustering: k-mediods, CLARA, DENCLUE, DBSCAN, Kohonen networks, BIRCH clustering, Outlier detection using Clustering, Probabilistic model based clustering. Market Basket Analysis: Association rules and prediction, Apriori Algorithm, data attributes, applications to electronic commerce. Text mining, sentiment analysis.	**(15)**

Course Outcomes: Students should able to

1. Understand and clean the big data sets.
2. Apply classification methods to real life problems in various fields.
3. Select and evaluate the models based on datasets using different modelling techniques.
4. Make different clusters of dataset and also they will able to do market basket analysis.

BOOKS RECOMMENDED:

1. Berson and S. J. Smith, Data warehousing, Data Mining, and OLAP (McGraw-Hill., 1997)
2. J.H. Breiman, R.A. Friedman, Olshen and C.J. Stone, Classification and Regression Trees (Wadsworth and Brooks / Cole., 1984)
3. Jiawei Han, Micheline Kamber and Jian Pei, Data Mining: Concepts and Techniques (Elsevier, 3rd Edition.,2012)
4. T. M. Mitchell, Machine Learning (McGraw-Hill.,1997)
5. B. D. Ripley, Pattern Recognition and Neural Networks (Cambridge University Press.,1996)
6. V. N. Vapnik, The nature of Statistical learning theory (Springer, 2000)

MST 305: CLINICAL TRIALS

Course Objectives: Student will able to

1. Understand fundamentals of clinical trials in order to deepen the understanding of clinical trials that are very important part of the any medicine.
2. Learn and develop scientific view to study the statistical challenges of clinical comparison of two or more treatments in human subjects.
3. Aware of the use of the cross-over design and its limitations.
4. Develop the skills to analyse the clinical trial data.

Credits=4	MST 305: CLINICAL TRIALS	No. of hours per unit / credits
Credit –1 UNIT I	Introduction to clinical trials: the need and ethics of clinical trials, bias and random error in clinical studies, conduct of clinical trials, overview of Phase I-IV trials, multi-center trials. Data management: data definitions, case report forms, database design, data collection systems for good clinical practice, Concept of Randomization and blinding.	**(15)**
Credit –1 UNIT II	Design of clinical trials: parallel vs. cross-over designs, cross-sectional vs. Longitudinal designs, review of factorial designs, objectives and endpoints of clinical trials, International Conference on Harmonization (ICH), Brief history of ICH, Structure of ICH Harmonization Process, Guidelines for Good Clinical Practice Glossary, The Principles of ICH GCP Institutional Review Board / Independent Ethics Committee, Introduction of E9 and E6 Guideline, Concept of Clinical Trial Protocol and Statistical Analysis Plan (SAP).	**(15)**
Credit –1 UNIT III	Concept of Pharmacokinetics parameters, Design of bioequivalence trials, Classical methods of interval hypothesis, testing for bioequivalence Baysian methods, non-parametric methods, Assesment of inter and intra subject variability, drug interaction study, Dose proportionality steady state analysis, Clinical end points, alpha spending function.	**(15)**
Credit –1 UNIT IV	Analysis and Reporting of clinical trials: Concept of sample size and it's calculation, Analysis of categorical outcomes from Phase I - III trials, analysis of survival data from clinical trials.	**(15)**

Course Outcomes: Students should able to

1. Understand need and ethics of any clinical trial and how to conduct clinical trial of any medicine in different phases.
2. Apply various designs of clinical trials to the data.
3. Understand the designs of clinical trials.
4. Analyse and report the clinical trials.

BOOKS RECOMMENDED:

1. S. Piantadosi, Clinical Trials: A Methodologic Perspective (Wiley and Sons,1997)
2. Shein-Chung Chow and Jein-Pei Liu, Design and analysis of clinical trials: Concept and Methodologies, (Wiley Series in probability and statistics, second edition 2000)
3. C. Jennison and B. W. Turnbull, Group Sequential Methods with Applications to Clinical Trials (CRC Press.,1999)
4. L. M. Friedman, C. Furburg, D. Demets, Fundamentals of Clinical Trials (SpringerVerlag.,1998)
5. J. L. Fleiss, The Design and Analysis of Clinical Experiments (Wiley and Sons., 1989)
6. Todd A Durham & J. Rick Turner, Introduction to Statistics in Pharmaceutical Clinical Trials (Pharmaceutical Press, 2008)

MSP 316: PRACTICAL-III

Course Objective: Student will able to

1. Understand and implement theory in real life problems.
2. Apply inferential statistical techniques to solve real life problems.
3. Data handling by using data mining's techniques.
4. Data analysis and application of Multivariate analysis.

Credits=4	**MSP 316: PRACTICAL-III**	No. of hours per unit / credits
	1. Construction of Consistent/CAN Estimators. 2. Construction of BAN Estimators and confidence interval based on it. 3. Confidence interval based on CAN. 4. Confidence interval based on VST. 5. Parametric analysis of survival data. 6. Estimation of Survival Function. 7. Estimation of parameters in PH model. 8. Analysis of two sample non-parametric problem. 9. Classification. 10. Cluster Analysis. 11. Artificial Neural Network. 12. Support Vector Machine. 13. Exploratory data analysis. 14. Application of Hotelling's T2 statistics 15. Discriminant Analysis 16. Principle component analysis and Factor Analysis. 17. Pharmokinetics. 18. Confidence interval. 19. Analysis of categorical outcomes. 20. Non-parametric test based on Clinical Trials.	

Course Outcomes: Students should able to understand

1. Construction of Estimators and obtaining confidence interval.
2. Estimation of Survival Function and parameters.
3. Discriminant Analysis, PCA and Factor Analysis.
4. Data analysis and Non-parametric test based on Clinical Trials.

BOOKS RECOMMENDED:

1. B. K. Kale, A first course on parametric inference (Narosa Pub.,1999)
2. R. G. Miller, Survival Analysis (John Wiley and Sons., 1981)
3. D. C. Montgomery, E. A. Peck and G. G. Vining, Introduction to Linear Regression Analysis (Wiley, 2003)
4. Berson and S. J. Smith, Data warehousing, Data Mining, and OLAP (McGraw- Hill.,1997)
5. S. Piantadosi, Clinical Trials: A Methodologic Perspective (Wiley and Sons,1997)

MST 401: OPTIMIZATION TECHNIQUES –II

Course Objectives: Student will able to

1. The basic components of optimization problem.
2. Understand formulation of problem as mathematical programming problem.
3. Concept of goal programming problem, inventory model, EOQ, replacement problem.
4. Learn advanced methods in operations research course that are used in the systems approach to Engineering and Management.

Credits=4	**SEMESTER-IV** **MST 401: OPTIMIZATION TECHNIQUES –II**	**No. of hours per unit / credits**
Credit –1 UNIT I	**Goal Programming:** Meaning & Concept of GP, Difference between LP & GP Approach, Model Formulation, Graphical Method to Solve GP, Modified Simplex Method.	**(15)**
Credit –1 UNIT II	**Deterministic inventory models:** The meaning of inventory control, factors involved in inventory problem, inventory model building, Concept of EOQ, i) **Single item inventory control models without shortages:** Model I (a): EOQ model with constant rate of demand. Model I (b): EOQ model with different rates of demand in different cycles. Model I (c): Economic lot size with finite Rate of replenishment. (EOQ production model) ii) **Single item inventory control models with shortages:** Model II(a): EOQ model with constant demand and variable order cycle time, Model II(b): EOQ model with constant demand and fixed reorder cycle time, Model II (c): The production lot size model with shortages.	**(15)**
Credit –1 UNIT III	**Probabilistic Inventory Models. Introduction** i) **Instantaneous Probabilistic Demand Without Set-up Cost Models: Model I:** Optimal Order Point-Marginal Analysis Approach, Model II: EOQ Under Uncertain Demand in a single Period, Model III: Instantaneous Demand, Discrete Replenishment. Model IV: Instantaneous Demand, Continuous Replenishment. Model V: Reorder Lead Time Without Set-up Cost. ii) **Continuous Probabilistic Demand Without Setup Cost Models: Model I(a):** Continuous Demand, Discrete Replenishment. Model I(b): Continuous Demand, Continuous Replenishment. **Instantaneous Probabilistic demand with Set-up Cost Model: Model I:** Instantaneous Demand, Continuous Replenishment.	**(15)**
Credit –1 UNIT IV	**Replacement Problems**, Types of failure: Gradual failure, Sudden failure i) **Replacement policy for items whose efficiency deteriorates with time:** when value of money remains constant and when value of money changes ii) **Replacement of items that completely fail:** Mortality tables, mortality theorem, individual and group replacement policy.	**(15)**

Course Outcomes: Students should able to

1. Understand meaning of goal programming, distinguish between LP and GP.
2. Understand problem of inventory control, factor affecting on it, their model building and concept of EOQ.
3. Understand application of inventory models.

4. Analyse replacement problem and various replacement policies, their applications in real life.

BOOKS RECOMMENDED:

1. G. Hadley, Linear Programming (Addison Wesley.,1969)
2. H. A. Taha, Operation Research An Introduction (Macmillan,1971)
3. Kanti Swaroop & Gupta M. M., Operations Research (Sultan Chand & P. Gupta,1985)
4. D. S. Hira, Operation Research (Sultan Chand & Co.ltd.,2010)
5. J. K. Sharma, Operation Research Theory and Applications (Macmillan., 2003)
6. Subhash C. Ray, Data envelopment analysis: theory and techniques for economics and operations research (Cambridge University Press, 2004)

MST 402: STOCHASTIC PROCESSES

Course Objectives: Student will able to

1. Learn and understand stochastic processes predictive approach.
2. Develop the ability to analyse and apply some basic stochastic processes for real life situations.
3. Study the distribution of first passage time, Long-run distribution, conditional joint distribution of inter arrival times.
4. Understand different process and models.

Credits=4	**MST 402: STOCHASTIC PROCESSES**	**No. of hours per unit / credits**
Credit –1 UNIT I	a) Stochastic process: Definition, Classification of Stochastic processes according to state space and time domain, Transition Probability Matrix, Markov chain, Examples of Markov Chain Formulation of Markov Chain models, initial distribution. b)Chapman-Kolmogorov Equation, calculation of n-step transition probabilities, Classification of States and Limiting Distributions.	**(15)**
Credit –1 UNIT II	a) First entrance theorem, first passage time distribution, random walk model, Gambler's ruin problem. b) Long-run distributions of Markov chain, relation with mean recurrence time, stationary distribution.	**(15)**
Credit –1 UNIT III	Poisson process, distribution of inter arrival times, conditional joint distribution of inter arrival times, compound Poisson process, Birth and death processes, Growth model with immigration and related results , Queueing systems, Markovian and non-Markovian queueing systems, embedded Markov chain applications to M/G/1.	**(15)**
Credit –1 UNIT IV	a) Renewal and delayed renewal processes, equilibrium (Stationary) renewal process, related theorems, key renewal theorem, Galton Watson Branching process. probability of ultimate extinction. b) Simulation of Markov Chain, Poisson process and branching process.	**(15)**

Course Outcomes: Students should able to understand

1. The stochastic processes, Markov chain and Transition probability matrix, various types of states and limiting distribution.

2. The random walk model, Gambler Ruin Problem and able to compute long run distribution of Markov chain.
3. Apply the Poisson process, Birth and Death process and various Queuing systems in real life.
4. The branching process and able to make simulation of Markov Chain, Poisson process and branching process.

BOOKS RECOMMENDED:

1. J. Medhi, Stochastic Process (Wiley Eastern.,1982)
2. Karlin & Taylor, A First Course in Stochastic Process, Academic Press., Vol. -1 (Academic Press, New York, 1975)
3. E. Cinlar, Introduction to Stochastic Process (Prentice Hall, 1974)
4. Sheldon M. Ross, Introduction to Probability Module (Eleventh Edition, Academic Press elsevier.com. 2014)
5. William Feller, An Introduction to Probability Theory and Its Applications (Vol. 1, 3rd Edition. Wiley,1968)
6. P. Hoel, S. Port, C. Stone, Introduction to Stochastic Processes (Waveland Pr Inc. publisher 1972)

MST 403: TIME SERIES ANALYSIS

Course Objective: Student will able to

1. Develop the necessary skills to identify the nature of the phenomenon represented by the sequence of observations and forecasting future values.
2. Learn and develop scientific view to understand the time series data and its analysis.
3. Learn stationary and non-stationary, and seasonal and non-seasonal time series models.
4. Learn to estimate model parameters and compare different models developed for the same dataset in terms of their estimation and prediction accuracy.

Credits=4	**MST 403: TIME SERIES ANALYSIS**	**No. of hours per unit / credits**
Credit –1 UNIT I	Time series as a discrete parameter stochastic process, types of variation in time series Auto - Covariance, Autocorrelation functions and their properties. Partial auto covariance function. Stationary time series, Exploratory time series analysis, Exponential and moving average smoothing, Holt –Winter smoothing, forecasting based on smoothing. Portmanteau tests for noise sequences, transformation to obtain Gaussian Series.	**(15)**
Credit –1 UNIT II	Wold representation of linear stationary processes, linear time series models: Autoregressive, Moving Average, Autoregressive Moving Average models. Concept of Causality, invertibility, computation of -weights and ψ- weights, computation of ACVF, ACF and PACF. Autoregressive Integrated Moving Average models.	**(15)**
Credit –1 UNIT III	Estimation of ARMA models: Yule-Walker estimation for AR Processes, Maximum likelihood and least squares estimation for ARMA Processes, Discussion (without proof) of estimation of mean, Auto-covariance and auto-correlation function under large samples theory, Durbin-Levinson algorithm, Innovation algorithm. Residual analysis and diagnostic checking. Minimum mean squared error Forecasting for ARIMA models. Introduction to SARIMA models.	**(15)**

Credit –1 UNIT IV	Introduction to spectral analysis, Spectral Representation of the ACVF, Spectral density of an ARMA process, its computation for simple models. Introduction to ARCH and GARCH models. Properties and estimation under ARCH(1) and GARCH(1,1) model, Estimation and forecasting extension of ARCH and GARCH. Transfer function models (Time series regression).	**(15)**

Course Outcomes: Students should able to

1. Remove trend and seasonality using different methods to convert the time series into stationary.
2. Understand time series, auto-covariance, auto-correlation their properties, various smoothing techniques.
3. Obtain Causality and inevitability, π -weights and ψ- weights, ACVF, ACF, PACF.
4. Understand estimation of ARIMA model, residual analysis and diagnostic checking, their forecasting.

BOOKS RECOMMENDED:

1. George E. P. Box, Gwilym M. Jenkins, Gregory C. Reinsel, Greta M. Ljung, Time Series Analysis: Forecasting and Control (5th Edition, Wiley 2015)
2. P. J. Brockwell and R. A. Davis, Time Series: Theory and Methods (Springer ,1987)
3. R. S. Tsay, Analysis of Financial Time Series (3rd Ed, Wiley Series in Prob. and Statistics 2010)
4. M.G. Kendall, Time Series, (Charler Graffin,1978)
5. C. Chatfield ,The Analysis of Time Series - An Introduction (Sixth edition, Chapman and Hall,2004)
6. James D. Hamilton, Time Series Analysis (Princeton University Press, 1994)

MST 404: PLANNING AND ANALYSIS OF INDUSTRIAL EXPERIMENTS

Course Objective: Student will able to

1. Develop the necessary skills of students to plan the experiments so that data obtained can be analyzed to yield valid and objective conclusions.
2. Develop scientific view to analyze the industrial data about specific perspective.
3. Understand factorial experiments and concept of confounding.
4. Aware about simulation study and model building.

Credits=4	**MST 404: PLANNING AND ANALYSIS OF INDUSTRIAL EXPERIMENTS**	**No. of hours per unit / credits**
Credit –1 UNIT I	**Review:** Basic concepts of design of experiment. Methods to study Analyzing Design, Nested and Split Plot Design. **2^k factorial Experiments**: Concepts of main effects, interaction, their graphical representation, Analysis of full 2k replicated and un-replicated factorial designs. **Concept of Confounding:** Total and partial confounding, construction and analysis confounded design.	**(15)**

Credit –1 UNIT II	**3^k factorial Experiments:** Concepts of main effects, interaction, their graphical representation, linear and quadratic components, Analysis of full 3^k replicated and un- replicated factorial designs. **Confounding:** construction and analysis confounded design, Factorials with mixed levels.	**(15)**
Credit –1 UNIT III	**Fractional Factorial:** Fractional replication for symmetric factorials, concept of generator, defining contrasts, aliasing, resolution and minimum aberration, construction and analysis of 2^{k-p} and 3^{k-p}fractional designs, Central composite designs.	**(15)**
Credit –1 UNIT IV	Introduction to model, History of Modeling, latest development in Modeling, Principle of modeling, Characteristics, Merits and Demerits of Model, Introduction to simulation, General concept in discrete event simulation, Random number generation, Nature of Simulation, Simulation models, Monte-Carlo simulation, Event type simulation, Demand pattern Simulation, Merits and Demerits of Simulation.	**(15)**

Course Outcomes: Students should able to

1. Understand the basic concepts of design of experiments, concept of confounding.
2. Analyse different factorial and fractional experiments their interactions, graphical representation and confounding.
3. Understand fractional factorial design.
4. Apply simulation techniques.

BOOKS RECOMMENDED:

1. D. C. Montgomery, Design and Analysis of Experiments (8^{th} edition, WileyIndia PvtLtd., 2013)
2. O. L. Davies,F. J. van Dun En,H. C. Hamaker, The design and analysis of industrial experiment (Oliver & Boyd, 1995)
3. D. Voss and A. Dean Design and Analysis of Experiments (Springer verlag Gmbh.,1999)
4. C. F. Jeff Wu, Michael S. Hamada, Experiments: Planning, Analysis and Parameter Design Optimization (Wiley & Sons.,2nd edition, 2000)
5. William G. Cochran, Gertrude M. Cox, Experimental Design (New York: John Wiley & Sons, 1959)

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MST 405: ACTUARIAL STATISTICS

Course Objective: Student will able to

1. Develop the necessary skills of students to understand the insurance business and to design insurance policies.
2. Learn the life tables used in insurance products.
3. Learn the concept of interest, different life insurance products, life annuities, net premiums.
4. Motivate students to prepare for exams required for employment in the actuarial science profession.

Credits=4	**MST 405: ACTUARIAL STATISTICS**	**No. of hours per unit / credits**
Credit –1 UNIT I	Introduction to Insurance Business, Concept of risk, types of risk, characteristics of insurable risk, Risk models for Insurance: Individual and aggregate Risk models for short term, Distribution of aggregate claims, compound Poisson distribution and its applications. Survival function and Life tables: Survival function, Distribution function, Density functions and Force of mortality. Time-until death random variable and Curtate-future lifetime random variable.	**(15)**
Credit –1 UNIT II	Life tables, Select and ultimate life tables. Assumptions for fractional ages and some analytical laws of mortality. Life Insurance: Principles of compound interest: Nominal and effective rates of interest and force of interest and discount, compound interest, Insurance payable at the moment of death and at the end of the year of death ,Whole life insurance, endowment insurance, term insurance, deferred insurance and varying benefit insurance.	**(15)**
Credit –1 UNIT III	Annuities: annuity certain, discrete annuity, monthly annuity, continuous annuity, deferred annuity, present values and accumulated values of these annuities, Continuous life annuity, discrete life annuity, such as whole life annuity, temporary life annuity, n-year certain and life annuity, life annuities with mthly payments, Present value random variables for these annuity payments, their means and variances, Actuarial present value of the annuity.	**(15)**
Credit –1 UNIT IV	Loss at issue random variable, various principles to decide net premiums for insurance products and annuity schemes defined in unit II and III, fully continuous premiums and fully discrete premiums, True monthly payment premiums. Extended equivalence principle to decide gross premiums, Concept of reserve, Fully continuous reserve, Fully discrete reserve.	**(15)**

Course Outcomes: Students should able to

1. Understand the insurance business, concept of risk and claims.
2. Compute the life tables.
3. Compute various types of annuities.
4. Understand various principles to decide premiums

BOOKS RECOMMENDED:

1. Deshmukh S. R., An Introduction to Actuarial Statistics (University Press., 2009)
2. Robin Cunningham, Thomas N. Herzog, Richard L., Models for Quantifying Risk (4th Edition, ACTEX Publications, 2011)
3. David C. M. Dickson, Mary R. Hardy and Howard R. Waters, Actuarial Mathematics for life contingent risks (International series on actuarial science, Cambridge 2009)
4. Uma Narang, Insurance Industry in India: Features, Reforms and Outlook, Uma New Century Publications, 2013)

MSP 406: PRACTICAL-IV

Course Objective: Student will able to

1. Understand and implement theory in real life problems.
2. Apply operations research techniques to solve real life problems.
3. Apply different designs and time series techniques in real life situations.
4. Construction of t.p.m. and probability findings.

Credits=4	MSP 416: PRACTICAL-IV	No. of hours per unit / credits
	1. Goal Programming. 2. Deterministic inventory models 3. Replacement Problems 4. Probabilistic inventory models 5. Realization of stochastic process. 6. Classification of t.p.m. and computation of n- step probability matrix. 7. Classification of states: Computations of absorption probabilities. 8. Stationary distribution and recurrence time. 9. Auto covariance and Autocorrelation. 10. Causal and Invertible 11. Smoothing the series 12. Forecasting. 13. Analysis of full replicated un confounded 2^n and 3^n factorial experiments. 14. Analysis of single replicated 2^n and 3^n factorial experiments. 15. Analysis of confounded 2^n and 3^n factorial experiments: total and partial confounding. 16. Simulation using Monte-Carlo method. 17. Construction of Life Tables. 18. Computations of benefit premiums for n-year term insurance, whole life insurance, endowment insurance. 19. Computation of Annuities. 20. Computation of Reserve.	

21. Goal Programming.
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23. Replacement Problems
24. Probabilistic inventory models
25. Realization of stochastic process.
26. Classification of t.p.m. and computation of n- step probability matrix.
27. Classification of states: Computations of absorption probabilities.
28. Stationary distribution and recurrence time.
29. Auto covariance and Autocorrelation.
30. Causal and Invertible

31. Smoothing the series
32. Forecasting.
33. Analysis of full replicated un confounded 2^n and 3^n factorial experiments.
34. Analysis of single replicated 2^n and 3^n factorial experiments.
35. Analysis of confounded 2^n and 3^n factorial experiments: total and partial confounding.
36. Simulation using Monte-Carlo method.
37. Construction of Life Tables.
38. Computations of benefit premiums for n-year term insurance, whole life insurance, endowment insurance.
39. Computation of Annuities.
40. Computation of Reserve.

Course Outcomes: Students should able to

1. Solve the problems of goal programming, inventory, replacement and DEA.
2. Do classification of t.p.m., state space and computation of probability matrix.
3. Recognize trend of data and use appropriate time series model.
4. Construction of life tables and computation of benefit premiums, annuities and reserve.

REFERENCE BOOKS:

1. J. K. Sharma, Operation Research Theory and Applications (Macmillan., 2003)
2. J. Medhi, Stochastic Process (Wiley Eastern.,1982)
3. M.G. Kendall, Time Series, (Charler Graffin,1978)
4. D. C. Montgomery, Design and Analysis of Experiments (8^{th} edition, WileyIndia PvtLtd., 2013)
5. Deshmukh S. R., An Introduction to Actuarial Statistics (University Press., 2009)

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