University of Mumbai

No. UG/ 120 of 2019-20

CIRCULAR:-

Attention of the Principals of the Affiliated Colleges the Head of the University Departments and Directors of the recognized Institutions in Humanities, Science & Technology Faculties is invited to the syllabus uploaded by Academic Authority Unit which was accepted by the Academic Council at its meeting held on 27th February, 2013 **vide** item No. 4.125 relating to the revised syllabus as per the (CBSGS) for M.A./M.Sc. Course in Statistics (Sem. III & IV).

They are hereby informed that the recommendations made by the Board of Studies in Statistics at its meeting held on 19th June, 2019 have been accepted by the Academic Council at its meeting held on 26th July, 2019 **vide** item No.4.8 and that in accordance therewith, the revised syllabus as per the (CBCS) for the M.A./M.Sc. Part II Statistics (Sem. III & IV) has been brought into force with effect from the academic year 2019-20, accordingly. (The same is available on the University's website www.mu.ac.in).

(Dr. Vinod P. Patil)
I/c REGISTRAR

MUMBAI – 400 032
18th September, 2019

To

The Principals of the affiliated Colleges the Head of the University Departments and Directors of the recognized Institutions in Humanities, Science & Technology Faculties. (Circular No. UG/334 of 2017-18 dated 9th January, 2018.)

A.C/4.8/26/07/2019

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No. UG/ 120 -A of 2019-20 MUMBAI-400 032 18th September, 2019

Copy forwarded with Compliments for information to:-

1) The I/c Dean, Faculties of Humanities, Science & Technology,
2) The Chairman, Board of Studies in Statistics,
3) The Director, Board of Examinations and Evaluation,
4) The Professor-cum-Director, Institute of Distance and Open Learning (IDOL),
5) The Director, Board of Students Development,
6) The Co-ordinator, University Computerization Centre,

(Dr. Vinod P. Patil)
I/c REGISTRAR

Cover Page

AC 26/7/19
Item No. 4.8

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	M.A./M.Sc. part II Sem III & IV CBCS
2	Eligibility for Admission	M.A./ M.Sc. part I (Statistics)
3	Passing Marks	40% in internal and 40% in external
4	Ordinances / Regulations (if any)	N.A.
5	No. of Years / Semesters	two semesters
6	Level	P.G. / ~~U.G./ Diploma / Certificate~~ **(Strike out which is not applicable)**
7	Pattern	~~Yearly~~ / Semester **(Strike out which is not applicable)**
8	Status	~~New~~ / Revised **(Strike out which is not applicable)**
9	To be implemented from Academic Year	From Academic Year 2019-20

Date: 9-7-2019 Signature: VUDixit

Name of BOS Chairperson / ~~Dean~~: Dr.(Mrs.) V. U. Dixit

UNIVERSITY OF MUMBAI

Syllabus for the M. A./M. Sc. PART II
(Semester III and Semester IV)
Program: M. Sc.
Course : STATISTICS

(Choice Based Credit System with effect from the academic year 2019–2020)

M.A./ M.Sc. Part - II <Statistics>
(Semester III and Semester IV) Syllabus
Revised for choice based and credit system
To be implemented from the Academic year 2019-2020

Structure of the syllabus:
In both, semester III and semester IV, there are three compulsory courses each of four credits and one course of four credits can be selected from the available list of elective courses. In addition there are two practical courses each of four credits in semester III and one practical course of four credits and Statistical project of four credits in semester IV.

Following is the table showing the proposed courses (compulsory and elective) to be covered in semester III and semester IV of second year.

COURSE	PSST 301	PSST 302	PSST 303	PSST 304	PSST P3A & PSST P3B
SEMESTER III	MULTIVARIATE ANALYSIS- II	TESTING OF HYPOTHESES	PLANNING AND ANALYSIS OF EXPERIMENTS- II	ELECTIVE COURSE	STATISTICS PRACTICAL - V
					STATISTICS PRACTICAL - VI
COURSE	PSST 401	PSST 402	PSST 403	PSST 404	PSST P4A & PSST P4B
SEMESTER IV	STOCHASTIC PROCESSES	TIME SERIES ANALYSIS	RELIABILITY AND SURVIVAL ANALYSIS	ELECTIVE COURSE	STATISTICS PRACTICAL - VII
					STATISTICAL PROJECT

Duration of each of the theory courses, will be 120 hours which is further divided into two parts

Total number of classroom teaching hours	60
Total number of notional hours	60

Each theory course will be of four credits having four hours of classroom teaching per week.
Syllabus of each theory course is divided into four units each should be covered in 15 lectures each of one hour.

SEMESTER III

COMPULSORY COURSES
DETAILED SYLLABUS:

Unit	Course Code: PSST 301 Course Title: MULTIVARIATE ANALYSIS - II
I	Principal Component Analysis: population and sample principal components, principal components for special structure of dispersion matrix: diagonal matrix, correlation matrix, sample variation, interpretation of sample principal components, graphing the principal components, large sample inference, large sample confidence interval for eigenvalues, test for equal correlation structure.
II	Factor Analysis: introduction, methods of estimation: principal components method, maximum likelihood method. Factor rotation, factor scores.
III	Canonical Correlation and Variates: introduction, interpretation, sample canonical correlation and covariates, large sample inference.
IV	Cluster Analysis: similarity measures, hierarchical clustering methods and non-hierarchical methods. Multidimensional scaling.

REFERENCE BOOKS:

- Anderson, T. W. (2003): An Introduction to Multivariate Statistical Analysis. John Wiley. 3rd edition.
- Giri, N. C. (2003): Multivariate Statistical Analysis. CRC Press. 2nd edition.
- Hardle, W. K. and Hlavka, Z. (2015): Multivariate Statistics: Exercise and solutions. Springer.
- Johnson, R. A. and Wichern, D. W. (2015): Applied Multivariate Statistical Analysis. 6th Edition. PHI Learning Private Limited.
- Kshirsagar, A. M. (1979): Multivariate Analysis, Marcel Dekker Inc. New York.
- Mukhopadhyay, P. (2008): Multivariate Statistical Analysis. World Scientific.
- Srivastava, M. S. (2002): Methods of Multivariate Statistics. John Wiley.

Unit	Course Code: PSST 302 Course Title: TESTING OF HYPOTHESES
I	Fundamental notions of testing of hypothesis: Statistical hypothesis, simple and composite hypothesis, critical region, acceptance region, type I and type II errors, test function, test of hypothesis, power of test, power function. Best critical region, most powerful test, Neymann-Pearson lemma. uniformly most powerful (UMP) test, monotone likelihood ratio property of family of distributions, non existence of UMP.
II	Generalized Neymann-Pearson Lemma, Locally Most Powerful test (LMPT). UMP Unbiased test, Locally Most Powerful Unbiased test. Likelihood ratio test. Confidence sets: Uniformly Most Accurate (UMA), Uniformly Most Accurate Unbiased (UMAU) confidence sets. Sequential Probability Ratio Test (SPRT).

III	Definitions: Quantile, Quantile function, Empirical distribution function, Empirical quantile function. Point estimation and interval estimation of population quantiles. Test of hypotheses for population quantile. U-statistics: definition, properties, one sample and two sample theorem. One and two samples problems, Sign test and Wilcoxon's test, Wald Wolfowitz run test, Mann-Whitney U-test, Wilcoxon Rank-Sum test. Test for equality of k independent samples: Median test, Kruskal Wallis test, Friedman test.
IV	Goodness of fit tests: Chi-square goodness of fit test, Kolmogorov-Smirnov test – one and two sample tests. Measures of association and their tests of significance: Kendall's Tau coefficient, Spearman's coefficient of rank correlation.

REFERENCE BOOKS:

- Dixit, U. J. (2016): Examples in Parametric Inference with R, Springer.
- Gibbons, J. D. and Chakraborti, S. (2010): Nonparametric Statistical Inference. CRC Press. 5th Edition.
- Lehmann, E. L. and Romano, J. P. (2005): Testing Statistical Hypothesis, Springer. 3rd Edition.
- Randles, R. H. and Wolfe, D. A. (1979): Introduction to the theory of nonparametric statistics. John Wiley.
- Rohtagi, V. K. and A.K.M.AD. Ehsanes Saleh (2001): An Introduction to Probability and Statistics. John Wiley. 2nd Edition.
- Shao, J. (2005): Mathematical Statistics. Springer. 2nd Edition.
- Srivastava, M. K. and Srivastava, M. (2014) Statistical Inference: Testing of Hypotheses. PHI Learning private limited.
- Wald, A. (1947): Sequential Analysis.

Unit	**Course Code: PSST 303** **Course Title: PLANNING AND ANALYSIS OF EXPERIMENTS - II**
I	Partially balanced incomplete block design, Lattice design. Row Column Design, Latin Square design, Youden Square Design
II	Split Plot Design, Weighing designs, Hadamard Matrix and its relation to the weighing design, optimality of above design: A,D,E
III	3^k factorial design, confounding in 3^k factorial design, 3^k fractional factorial design. Factorial designs with mixed levels.
IV	Response surface methodology, the method of steepest ascent, analysis of second order response surface, experimental designs for fitting response surfaces. Evolutionary operations. Robust designs.

REFERENCE BOOKS:

- Chakrabarti, M. C. (1962): Mathematics of Design and Analysis of Experiments. Asia Publishing house.
- Das, M. N. and Giri, N. C. (2002): Design and Analysis of Experiments. New Age International. 2nd Edition.
- Dean, A., Voss, D, and Draguljic, D. (2017): Design and Analysis of Experiments. Springer. 2nd Edition.
- Kempthorne, O. and Hinkelman, K. (2008):- Design and analysis of experiments: Introduction to experimental design. Volume I. John Wiley. 2nd Edition.

- Kempthorne, O. and Hinkelman, K. (2005):- Design and analysis of experiments: Advanced experimental design. Volume II. John Wiley. 2nd Edition.
- Khuri, A. and Cornell, J. A. (1996): Response surfaces: Design and analyses. Marcel Dekker. 2nd Edition.
- Meyers, R. H., Montgomery, D. C. and Christine, M. (2016) : Response surface methodology: Process and Product Optimization using designed experiments. John Wiley. 4th Edition.
- Montgomery, D. C. (2017): Design and Analysis of Experiments. John Wiley. 9th Edition.
- Raghavarao, D (1988): Construction and Combinatorial Problems in Design of Experiments. Dover Pubns.
- Wu, C. F. Jeff and Hamada, M. (2002): Experiments: planning, analysis, and parameter design optimization, John Wiley.
- Shah, K. R. and Sinha, B. K. (1989): Theory of Optimal Designs. Springer.

ELECTIVE COURSES:

In Semester three, any one elective course is to be selected from the following five elective courses.

1. PSSTE1 304: FINANCIAL MATHEMATICS.
2. PSSTE2 304: ELEMENTS OF DATA SCIENCE.
3. PSSTE3 304: STATISTICAL PROCESS CONTROL.
4. PSSTE4 304: CATEGORICAL DATA ANALYSIS.
5. PSSTE5 304: MEASURE THEORY.

DETAILED SYLLABUS:

Unit	**Course Code: PSSTE1 304** **Course Title: FINANCIAL MATHEMATICS**
I	Interest rates, Binomial trees
II	Wiener processes and Ito's lemma, The Black-Scholes-Merton model
III	Value at Risk.
IV	Estimating volatilities and correlations.

REFERENCE BOOKS:

- Hull, J. C. (2006): Options, Futures and Other Derivatives, 6th Edition.
- Ross, S. M. (2011): An Elementary Introduction to Mathematical Finance. Cambridge University Press. 3rd Edition.
- Ruppert, D. (2004): Statistics and Finance: An Introduction. Springer.

Unit	**Course Code: PSST E2 304** **Course Title: ELEMENTS OF DATA SCIENCE.**
I	Introduction to Data Mining, Classification techniques, CART, Random forests, Bayesian classification and learning rules. Introduction to Big Data. Large dimension small size multivariate data analysis, tackling the problems of estimation and inference. Classification of Big Data, Screening and Variable Selection.

II	Dimension Reduction and Visualization Techniques, Algorithms for data-mining using multiple nonlinear and nonparametric regression, Lasso Regression, Projection Methods, penalty, ridge regression, Bootstrap methods.
III	Introduction to Nonlinear regression, introduction to Nonparametric regression, generalized additive models, kernel methods, neural network, Artificial Intelligence, machine learning. Introduction to Structured Data and Structural Equation Modeling.
IV	Neural Networks: Multi-layer perceptron, predictive ANN model building using back propagation algorithm, Exploratory data analysis using Neural Networks – self organizing maps. Genetic Algorithms, Neuro-genetic model building.

REFERENCE BOOKS:

- Breiman, L., Friedman, J. H., Olschen, R. A. and Stone, C.J. (1984): Classification of Regression Trees, Wadsowrth Publisher.
- Hand, D. J. , Mannila, H. and Smith, P. (2001): Principles of Data Mining, MIT Press, Cambridge.
- Hassoun, M. H. (1998): Fundamentals of Artificial Neural Networks, Prentice-Hall of India, New Delhi.
- Hardle, W.(1990): Applied Nonparametric Regression, Cambridge University Press.
- Hastie, T. and Tibshirani, R.(1990): Generalized Additive Models, Chapman and Hall, London.
- Hastie, T., Tibshirani, R. and Friedman, J. H. (2001): The elements of Statistical Learning: Data Mining, Inference & Prediction, Springer Series in Statistics, Springer- Verlag.
- Hastie, T., Tibshirani, R. and Wainwright, M. (2015): Statistical Learning with Sparsity: The Lasso and generalizations.
- Seber, G. A. F. and Wild, C. J. (1989): Nonlinear Regression, John Wiley.

Unit	**Course Code: PSST E3 304** **Course Title: STATISTICAL PROCESS CONTROL**
I	Process and Measurement System Capability Analysis. Cumulative sum and Exponentially Weighted Moving Average Control Charts.
II	Modified and Acceptance control charts. Group control charts for multiple-stream processes. Multivariate quality Control. SPC with correlated data.
III	Engineering Process Control, Process Design and Improvement with Designed Experiments, Process Optimization with Designed Experiments, Robust Deign and Signal to Noise Ratios.
IV	Introduction to Lean and six – sigma: Definition of Lean, 5 S in Lean, 7 wastes in lean, 5 principles of lean. Definition of six – sigma and definition of Lean six – sigma. DMAIC over view, Define phase : VOC,VOB,VOP,CTQ,COPQ ,Project charter, DPU, DPMO, Yield, Brain Storming, SIPOC, Cause and Effect diagram Measure phase: Process definition, Process Mapping, Value Stream Mapping, sigma calculation using sigma calculator, Gage R and R. Improve Phase: Multi voting, Delphi Technique, Nominal group technique, Kaizen. ISO 9000.

REFERENCE BOOKS:

1. Duncan, A. J. (1986): Quality Control and Industrial Statistics. Irwin. 5th Edition.
2. Grant, E. L. and Leavenworth, R. (2017): Statistical Quality Control. McGraw Hill. 7th Edition.
3. Johnson, N. L. (1977): Statistics and Experimental Design in Engineering and Physical Science. John Wiley.
4. Montgomery, D. C. (2004): Introduction to Statistical Quality Control. John Wiley. 4th Edition.
5. Muralidharan, K. (2015): Six sigma for organizational Excellence: A statistical approach. Springer.
6. Phadke, M. S. (1989): Quality Engineering Using Robust Design. Pearson.
7. Taguchi, G. (1986): Introduction to Quality Engineering: Designing quality into products and processes. Quality resources.

Unit	**Course Code: PSST E4 304** **Course Title: CATEGORICAL DATA ANALYSIS**
I	Models for binary response variables, log linear models, fitting log linear and logit models.
II	Building and applying log linear models, log linear-logit models for ordinal variables.
III	Multinomial response models, models for matched pairs.
IV	Analyzing repeated categorical response data, asymptotic theory for parametric models, estimation theory for parametric models

REFERENCE BOOKS:

- Agresti, A. (2012): Categorical Data Analysis. John Wiley. 3rd Edition.
- Cox, D. R. and Snell, E. J. (1989): The Analysis of Binary Data. CRC Press. 2nd Edition.
- Gokhale, D. V. and Kullback, S. (1978): The Information in Contingency Tables. Marcel Dekker.
- Hosmer, D. W. and Lemeshow, S. (2000): Applied Logistic Regression. John Wiley, 2nd Edition.

Unit	**Course Code: PSST E5 304** **Course Title: MEASURE THEORY**
I	Introduction to sets and classes, field, sigma field, Borel field. Measure Spaces: Measures, measures on intervals, properties of measures, outer measure, measureable sets, extension of measures, Lebesgue measure, non measurable sets, Measurable functions, convergence of measures, introduction to L_p spaces.
II	Integration: integral of measurable function, integrable functions, Fatou's lemma, monotone convergence theorem, dominated convergence theorem, Radon-Nikodym theorem, Hahn and Jordan decomposition theorem,
III	Product spaces, product measures, Fubini's theorem, convergence in measure, probability spaces.
IV	Conditional probability, conditional expectations, independence, Martingale theory, martingale convergence theorem, martingale central limit theorem.

REFERENCE BOOKS:

- Athreya, K. B. and Lahiri S. (2006). Measure Theory and Probability Theory, Springer.
- Billingsley, P. (1995). Probability and Measure, 3rd Edition, John Wiley.
- Chandra, T. and Gangopadhyay, S. (2017): Fundamentals of Probability Theory. Narosa Publishing House.
- Chung, K. L. (2001). A Course in Probability Theory, Third Edition, Academic Press.
- Doob, J. L. (1994): Measure Theory. Spring-Verlag.
- Halmos, P. R. (1950): Measure Theory. Spring-Verlag.
- Loeve, M. (1963): Probability theory. D. Van Nostrand compny Inc.

PRACTICAL COURSES:

PSST P3A	**STATISTICS PRACTICAL-V**
	Practicals Based on Multivariate Analysis II (PSST 301) and Testing of Hypothesis (PSST 302).
PSST P3B	**STATISTICS PRACTICAL-VI**
	Practicals Based on Planning and Analysis of Experiments-II (PSST 303) and Elected course (PSST 304).

Each batch of practical consists of 10 students.
Duration of each of the practical course, will be 120 hours which is further divided into two parts

Total number of practical hours	60
Total number of notional hours	60

Each practical course will be of four credits. Each practical will have four hours of practical session per week per batch of practical.

Contents of the practical courses, PSST P3A and PSST P3B are to be covered with the help of Statistical Softwares like SAS, SPSS, MINITAB, R-Environment etc.

Seminar: Case Studies listed in the paper to be discussed and brief summary should be prepared.
2 hours per week: (30 teaching hours + 30 notional hours)
= 60 hours
= 2 credits
Total number of credits for third semester:

Theory courses:	16
Practical courses:	08
Total	24

EXAMINATION PATTERN FOR THEORY COURSES

Each course will be evaluated in two parts,
Part A] Continuous Internal Evaluation (CIE) and
Part B] Semester End Examination (SEE)

CIE will be of 40 marks which will include one mid-semester test of 20 marks of one hour duration and other 20 marks are composed of any one or combinations of group discussion, viva-voce, open notebook test, surprise test, assignments, class participation etc to be conducted by respective teacher.

SEE will be a theory examination of 60 marks of three hours duration based on entire syllabus. The question paper will consist of five questions of 15 marks each. Student should answer any four questions out of five questions.

EXAMINATION PATTERN FOR PRACTICAL COURSES

At the end of semester there will be a practical examination of 100 marks and of three hours duration for each of the practical courses, PSST P3A and PSST P3B. The distribution of total of 100 marks is as given below,

Practical Examination	Viva	Journal	Total
80 marks	10 marks	10 marks	100 marks

SEMESTER IV

COMPULSORY COURSES
DETAILED SYLLABUS:

Unit	**Course Code: PSST 401** **Course Title: STOCHASTIC PROCESSES**
I	Introduction to stochastic processes, specification of stochastic processes, real life applications of stochastic processes, introduction to different types of stochastic processes. Markov chain, real life examples of Markov chain, order of a Markov chain, transition probabilities, Chapman-Kolmogorov equations, classification of states, periodicity, closed class, minimal closed class, stationary distribution of a Markov chain. Gamblers ruin problem, random walk. Concept of absorption probabilities, Statistical inference for Markov chains.
II	Continuous time Processes: Poisson process, Generalizations of Poisson process, birth and Death process. Brownian Motion, Wiener process, Kolmogorov equations.
III	Renewal Process: Renewal process in continuous time, renewal equation, stopping time, renewal theorem. Real life applications.
III	Branching Process: Introduction to branching process, probability generating function of branching process, moments, classification of states, identification of criticality parameter, extinction probability, relationship between criticality parameter and extinction probability of the process, Expression for mean and variance of the process. Extinction probability, Some applications.

REFERENCE BOOKS:

- Bhat, B.R. (2000). Stochastic Models: Analysis and Applications, New Age International.
- Bhat, U. N. and Miller, G. K. (2002): Elements of Applied Stochastic Processes. 3rd Edition. Wiley

- Basu, S (2012): Applied Stochastic Processes. New Central book agency.
- Durrett, R. (1999): Essentials of Stochastic Process.
- Hoel, P. G., Port, S. C. and Stone, C. J. (1972): Introduction to Stochastic Processes, Houghton Mifflin
- Karlin, S. and Taylor, H. M. (1975): First Course in Stochastic Processes second edition.
- Kulkarni, V. G. (2011): Modeling and Analysis of Stochastic Systems, Chapman and Hall, London.
- Medhi, J. (1994): Stochastic Processes Second edition, Wiley Eastern.
- Ross, S. M. (2004): Introduction to Probability Models, Wiley Eastern.

Unit	**Course Code: PSST 402** **Course Title: TIME SERIES ANALYSIS**
I	Real life examples of time series, types of variation in time series, exploratory time series analysis, tests of randomness, tests for trend, seasonality. Auto-covariance and auto-correlation functions and their properties, Exponential and Moving average smoothing. Holt -Winters smoothing. Forecasting based on smoothing, adaptive smoothing. Time - series as a discrete parameter stochastic process. Portmanteau tests for noise sequences, transformation to obtain Gaussian series. General linear processes.
II	Auto regressive (AR), Moving average (MA) and Autoregressive moving average (ARMA), Stationarity and invertibility conditions. Nonstationary and seasonal time series models: Auto regressive integrated moving average (ARIMA) models, Seasonal ARIMA (SARIMA) models, Transfer function models (Time series regression).
III	Estimation of mean, auto covariance and autocorrelation functions, Yule-Walker estimation. Forecasting in time series models, Durbin-Levinson algorithm, innovation algorithm.
IV	Estimation of ARIMA model parameters, Choice of AR and MA periods, FPE, AIC, BIC, residual analysis and diagnostic checking, Unit-root nonstationarity, unit-root tests, ARCH and GARCH models.

REFERENCE BOOKS:

- Brockwell, P. J. and Davis, R. A. (2003): Introduction to Time Series Analysis, Springer
- Chatfield, C. (2001): Time Series Forecasting, Chapman &Hall.
- Fuller, W. A. (1996): Introduction to Statistical Time Series, 2nd Ed. Wiley.
- Hamilton, N. Y. (1994): Time Series Analysis, Princeton University press.
- Kendall, M. and Ord, J. K. (1990): Time Series, 3rd Ed. Edward Arnold.
- Lutkepohl, H. (2005): New Introduction to Multiple Time Series Analysis, Springer
- Shumway, R. H. and Stoffer, D. S. (2010): Time Series Analysis & Its Applications, Springer.
- Tsay, R. S. (2010): Analysis of Financial Time Series, Wiley.

Unit	**Course Code: PSST 403** **Course Title: RELIABILITY AND SURVIVAL ANALYSIS**
I	Survival function, Hazard function, cumulative hazard function, reversed hazard function, nature of hazard function, bath-tub shape hazard function, class of increasing failure rate distributions, decreasing failure rate distributions, theorems. Relations between survival

	function, probability function, hazard function, cumulative hazard function, reversed hazard function. Lifetime distributions: exponential, Weibull, gamma, extreme value distributions, log-normal etc.
II	Reliability of the system: structure function, standard systems: series system, parallel system, k-out-of-n system, coherent system, path sets and path vectors, minimal path sets, cut sets and cut vector, minimal cut sets, reliability of coherent system, reliability bounds.
III	Introduction to Survival Analysis: need of survival analysis, censoring: left censoring, right censoring, interval censoring, random censoring, times censoring, order censoring, hybrid censoring. Kaplan-Meier estimator of survival function, properties of Kaplan-Meier estimator, Nelson-Aalen estimator of cumulative hazards function. Linear and log-transformed confidence interval for survival function and cumulative hazard function. Q-Q plot, hazards plot for lifetime distributions. Competing risk models.
IV	Regression models in Survival analysis: proportional hazards model, Accelerated failure time model, Cox proportional hazards model, residual analysis of proportional hazards model. Frailty models: Univariate frailty, multivariate frailty models, shared frailty, correlated frailty, additive frailty models. Using Weibull as baseline and gamma as frailty distribution.

REFERENCE BOOKS:

- Barlow, R. E. and Proschan, F. (1965): Mathematical theory of reliability
- Barlow, R. E. and Proschan, F. (1975): Statistical theory of reliability and life testing. Holt, Reinhart and Winston.
- Deshpande, J. V. and Purohit, S. G. (2005). Life Time Data: Statistical Models and Methods, World Scientific.
- Hanagal, D. D. (2011). Modeling Survival Data Using Frailty Models. CRC Press.
- Hosmer, D. and Lemeshow, S. (1999). Applied Survival Analysis: Regression Modeling of Time to Event Data, Wiley, New York.
- Kalbfleisch, J. D. and Prentice, R.L. (1986): The Statistical Analysis of Failure Time Data, John Wiley.
- Kleinbaum, D. G. and Klein, M. (2012). Survival Analysis**:** A Self-Learning Text, 3rd Ed, Springer, New York.
- Lawless, J.F.(1982): Statistical models and methods for life time data. John Wiley.
- Lee, E. T. and Wang, J. W. (2003). Statistical Methods for Survival Data Analysis, 3rd Edition. John Wiley.
- Liu, X. (2012). Survival Analysis: Models and Applications, Wiley, New York.
- Ross S. M. (2014): Introduction to Probability Models. Elsevier. 11th Edition.
- Smith, P.J. (2002): Analysis of Failure and Survival data. CRC.
- Wienke, A. (2011). Frailty Models in Survival Analysis, CRC.

ELECTIVE COURSES:

In Semester four, any one elective course is to be selected from the following five elective courses.

1. PSSTE1 404: ADVANCED THEORY OF DESIGNS.
2. PSSTE2 404: OPERATIONS RESEARCH.
3. PSSTE3 404: STATISTICAL DECISION THEORY
4. PSSTE4 404: STATISTICS IN INSURANCE.
5. PSSTE5 404: MODERN STATISTICAL INFERENCE.

DETAILED SYLLABUS:

Unit	**Course Code: PSST E1 404** **Course Title: ADVANCED THEORY OF DESIGNS**
I	Optimality of block designs, optimality of weighing designs
II	Two-level fractional factorial designs, process improvement with steepest ascent analysis of response surfaces.
III	Experimental designs for fitting response surfaces, response surface methods and Taguchi's robust parameter designs.
IV	Experiments with mixtures, analysis of mixture data.

REFERENCE BOOKS:

- Chakrabarti, M. C. (1962): Mathematics of Design and Analysis of Experiments. Asia Publishing house.
- Cornell, J. A. (2002): Experiments with Mixtures: Designs, Models and the Analysis of Mixture Data. John Wiley. 3rd Edition.
- Das, M. N. and Giri, N. C. (2002): Design and Analysis of Experiments. New Age International. 2nd Edition.
- Dean, A., Voss, D, and Draguljic, D. (2017): Design and Analysis of Experiments. Springer. 2nd Edition.
- Hinkelman, K. (2012): Design and analysis of experiments: Special Designs and Applications. Volume III. John Wiley.
- Kempthorne, O. and Hinkelman, K. (2008): Design and analysis of experiments: Introduction to experimental design. Volume I. John Wiley. 2nd Edition.
- Kempthorne, O. and Hinkelman, K. (2005): Design and analysis of experiments: Advanced experimental design. Volume II. John Wiley. 2nd Edition. =
- Khuri, A. and Cornell, J. A. (1996): Response surfaces: Design and analyses. Marcel Dekker. 2nd Edition.
- Meyers, R. H., Montgomery, D. C. and Christine, M. (2016) : Response surface methodology: Process and Product Optimization using designed experiments. John Wiley. 4th Edition.
- Montgomery, D. C. (2017): Design and Analysis of Experiments. John Wiley. 9th Edition.
- Raghavarao, D (1988): Construction and Combinatorial Problems in Design of Experiments. Dover Pubns.
- Wu, C. F. Jeff and Hamada, M. (2002): Experiments: planning, analysis, and parameter design optimization, John Wiley.
- Shah, K. R. and Sinha, B. K. (1989): Theory of Optimal Designs. Springer.

Course Code	**UNIT**	**OPERATIONS RESEARCH**

PSST 404	I	Linear programming problem: Review of Linear programming problem, convex set, Hyperplane, simples method, Revised simplex method, Dual simplex method.
	II	Integer Linear programming: Gomory cut method, branch and bound method, fractional cut method. Non-Linear programming: Kuhn-Tucker conditions of optimality. Quadratic programming; methods due to Beale, Wofle and Vandepanne, Duality in quadratic programming.
	III	Inventory Management: Introduction to Inventory control problem, Type of Inventory, Different cost in Inventory Problem, Selective control techniques Techniques of Inventory models : EOQ with known demand , uniform demand, problem of EOQ with shortages, Inventory model with stochastic demand , Buffer stock, price discounts. back order inventory models.
	IV	Queuing theory: Introduction of Queuing theory, Elements of a Queuing model, Pure birth and death model, specialized poison queues, single server models: (M/M/1):(GD/∞/∞), M/M/1:(GD/M/∞) , Multiserver models Data Envelopment Analysis (DEA) : meaning and use of DEA.

REFERENCE BOOKS:

- Hadley, G. (2002): Linear Programming. Narosa.
- Kambo, N. S. (2008): Mathematical Programming Techniques. Affiliated EastWest Press Pvt.
- Taha, H. A. (2010): Operations Research: An introduction. Pearson. 9th Edition.
- Winston, W. L. (2003): Operations Research: Applications and Algorithms. Cengage Learning. 4th Edition.
- Shanti swarup: Operations Research

Software:

1. Microsoft solver for topics 1 to 7
2. LINDO (Linear Interactive and Discrete Optimizer), LINGO for topics 1 to 7
3. Microsoft project for PERT and CPM
4. Crystal Ball for simulation

Unit	**Course Code: PSSTE3 404** **Course Title: STATISTICAL DECISION THEORY**
I	Formulation of decision problems, randomized and nonrandomized decision rules, illustrative examples, loss function, risk function, prior distributions, conjugate priors, posterior distributions.
II	Optimum decision rules, Bayes' rule, minimax rule, admissibility of rules, sufficiency and Rao-Blackwellization.
III	Bayes' test procedures, Bayesian estimation, credible sets, Bayesian hypothesis testing, Bayesian prediction.

IV	Empirical Bayes' analysis, Bayesian computations, Bayesian comparison.

REFERENCE BOOKS:

- Berjer, J. O. (1985): Statistical Decision Theory and Bayesian Analysis. Springer.
- Box, G. E. P. and Tiao, G. C. (1992): Bayesian Inference in Statistical analysis. John Wiley.
- DeGroot, M. H. (2004): Optimal Statistical Decision. John Wiley.
- Ferguson, T. S. (1967): Mathematical Statistics: A decision theoretic approach. Academic Press.
- Ghosh, B. K. (1970): Sequential Tests of Statistical Hypothesis. Addison-Wesley Publication.
- Savage, L. J. (1972): The foundations of Statistics. Dover Publications.

Unit	**Course Code: PSSTE4 404** **Course Title: STATISTICS IN INSURANCE**
I	Principles of Insurance. Need of Insurance. (Utility Theory). Difference between Banks and Insurance Companies. Brief history of Insurance.
II	Types of Insurance & Insurance products a. Life insurance - Term Assurance, Endowment Assurance, Annuities etc. b. Non-life insurance c. Health insurance Role of an Actuary. Actuarial Principles of Life and Health insurance including time value of money.
III	Gross Premium and Net Premium calculation. Life Insurance Reserves. Risk Premium calculation. Statistical distributions useful in General Insurance.
IV	Credibility Theory and Bayes' Theorem. Pension plans and Wealth Management. Risks - Types of Risk and Risk Management including Underwriting.

REFERENCE BOOKS:

- Black, K. and Skipper, H. D. (2015): Life insurance. Lucretian
- Bowers, N. L.. Gerber, H. U., Hickman, J. C., Jones, D. A. and Nesbitt, C. J. (1997): Actuarial Mathematics. Society of Actuaries of London. 2nd Edition.

Unit	**Course Code: PSST E5 404** **Course Title: MODERN STATISTICAL INFERENCE.**
I	Bayesian inference: Point estimators, Bayesian HPD confidence intervals, testing, credible intervals, prediction of a future observation Model selection and hypothesis testing based on objective probabilities and Bayes' factors large sample methods: Limit of posterior distribution, consistency of posterior distribution, asymptotic normality of

	posterior distribution.
II	EM algorithm: Incomplete data problems, E and M steps, convergence of EM algorithm, standard errors in the context of EM algorithm, applications of EM algorithm, Bayesian approach to EM algorithm.
III	MCMC methods: Methods of generating random sample, Metropolis-Hastings and Gibbs Sampling algorithms, convergence, applications, Bayesian approach.
IV	Bootstrap methods, estimation of sampling distribution, confidence intervals, failure of Bootstrap, variance stabilizing transformation, Jackknife and cross-validation, applications.

REFERENCE BOOKS:

- Bolstad, W. M. (2010): Understanding computational Bayesian statistics. John Wiley.
- Bolstad, W. M. (2017): Introduction to Bayesian Statistics. John Wiley. 3rd Edition.
- Congdon, P. (2006). Bayesian Statistical Modeling, John Wiley
- Davison, A.C. and Hinkley, D.V. (1997) Bootstrap methods and their Applications. Chapman and Hall.
- Efron, B. and Hastie, T. (2016). Computer Age Statistical Inference: Algorithms, Evidence and Data Science. Cambridge University Press.
- Gamerman, D. (1997): Markov chain Monte Carlo: Stochastic simulation for Bayesian inference. Chapman and Hall.
- Gelman, A., Carlin, J. B., Stern, H. S. and Rubin, D. B. (2003): Bayesian Data Analysis, Chapman and Hall. 2nd Edition.
- Gilks, W. R., Richardson, S., and Spiegelhalter, D. (eds.) (1995) Markov Chain Monte Carlo in Practice. Chapman and Hall.
- Kundu, D. and Basu, A. (2009): Statistical Computing: Existing Methods and Recent Developments. Narosa.
- McLachlan, G.J. and Krishnan, T. (2008): The EM Algorithms and Extensions. Wiley.

PRACTICAL COURSES:

PSST P4A	**STATISTICS PRACTICAL-VII**
	Practicals Based on all Four Theory courses
PSST P4B	**PROJECT**
	Statistical project for a group of students.

Each batch of practical consists of 10 students.
Duration of the practical course, will be 120 hours which is further divided into two parts

Total number of practical hours	60
Total number of notional hours	60

Practical course will be of four credits. Each practical will have four hours of practical session per week per batch of practical.

Contents of the practical course, PSST P4A are to be covered with the help of Statistical Softwares like SAS, SPSS, MINITAB, R-Environment etc.

Seminar: Case Studies listed in the paper to be discussed and brief summary should be prepared.
2 hours per week: (30 teaching hours + 30 notional hours)
= 60 hours
= 2 credits

Total number of credits for fourth semester:

Theory courses:	16
Practical courses:	08
Total	24

EXAMINATION PATTERN FOR THEORY COURSES

Each course will be evaluated in two parts,
Part A] Continuous Internal Evaluation (CIE) and
Part B] Semester End Examination (SEE)

CIE will be of 40 marks which will include one mid-semester test of 20 marks of one hour duration and other 20 marks are composed of any one or combinations of group discussion, viva-voce, open notebook test, surprise test, assignments, class participation etc to be conducted by respective teacher.

SEE will be a theory examination of 60 marks of three hours duration based on entire syllabus. The question paper will consist of five questions of 15 marks each. The student should answer any four questions out of five questions.

EXAMINATION PATTERN FOR PRACTICAL COURSES

At the end of semester four there will be a practical examination of 100 marks and of three hours duration for the practical courses, PSST P4A. The distribution of total of 100 marks is as given below,

Practical Examination	Viva	Journal	Total
80 marks	10 marks	10 marks	100 marks

Course PSST P4B is evaluated based on the project report submitted by the students and presentation based on the analysis of project as,

Guide's assessment	External judge's Assessment at the time of presentation	Viva	Total
40 marks	40 marks	20 marks	100 marks

Note: It is resolved that the examination pattern for Theory courses of M.Sc. part I (sem I and sem II) for continuous internal evaluation (CEE) of 40 marks will be same as M.Sc. part II (sem III and sem IV) from the academic year 2019-2020.