Estd. 1962
"A++" Accredited by NAAC (2021)
With CGPA 3.52

SHIVAJI UNIVERSITY, KOLHAPUR - 416004, MAHARASHTRA
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शिवाजी विद्यापीठ, कोल्हापूर -४१६००४,महाराष्ट्र
दूरध्वनी-ईपीएबीएक्स -२६०९०००, अभ्यासमंडळे विभाग दुरध्वनी ०२३१—२६०९०९४
०२३१—२६०९४८७

SU/BOS/Science/473 **Date: 19/08/2024.**

To,

The Principal, All Concerned Affiliated Colleges/Institutions Shivaji University, Kolhapur	The Head/Co-ordinator/Director All Concerned Department (Science) Shivaji University, Kolhapur.

Subject: Regarding Minor Change syllabi of M.Sc. Part-I & II as per NEP-2020 (2.0) degree programme under the Faculty of Science and Technology.

Ref: SU/BOS/Science/482 Date: 01/07/2023 & 09 Date: 02/01/2024

Sir/Madam,

With reference to the subject mentioned above, I am directed to inform you that the university authorities have accepted and granted approval to the Minor Change in syllabi, nature of question paper and equivalence of M.Sc. Part-I & II as per NEP-2020 (2.0) degree programme under the Faculty of Science and Technology.

M.Sc. Part-I & II as per NEP-2020 (2.0)			
1.	Statistics	2.	Applied Statistics and Informatics

This syllabus, nature of question shall be implemented from the academic year 2024-2025 onwards. A soft copy containing the syllabus is attached herewith and it is also available on university website www.unishivaji.ac.in,NEP-2020@suk(Online Syllabus).

The question papers on the pre-revised syllabi of above-mentioned course will be set for the examinations to be held in October /November 2024 & March/April 2025. These chances are available for repeater students, if any.

You are, therefore, requested to bring this to the notice of all students and teachers concerned.

Thanking you,

Dy Registrar
Dr. S. M. Kubal

Copy to:

1	The Dean, Faculty of Science & Technology	4	P.G Admission / Eligibility Section
2	The Chairman, Respective Board of Studies	5	Computer Centre/ Eligibility Section
3	B.Sc. Exam/ Appointment Section	6	Affiliation Section (U.G.) (P.G.)

SHIVAJI UNIVERSITY, KOLHAPUR

Established: 1962

A^{++} Accredited by NAAC (2021) with CGPA 3.52

Structure and Syllabus in Accordance with

National Education Policy – 2020 (NEP 2.0)

with Multiple Entry and Multiple Exit

of

Master of Science (Statistics) Part II

under
Faculty of Science and Technology

(To Be Implemented From Academic Year 2024-25)

Courses

M.Sc. Semester-III			
Sr. No.	**Course Category**	**Course Title**	**Course Code**
1	Major Mandatory	Stochastic Processes	MSU0325MML937I1
2		Theory and Practice of Machine Learning	MSU0325MML937I2
3		Multivariate Analysis	MSU0325MML937I3
4		Practical-III	MSU0325MMP937I4
5	Major Elective*	Design and Analysis of Experiments	MSU0325MEL937I1
6		Econometrics	MSU0325MEL937I2
7		Functional Data Analysis	MSU0325MEL937I3
8	Research Project	Research Project	MSU0325RPP937I
M.Sc. Semester-IV			
Sr. No.	**Course Category**	**Course Title**	**Course Code**
1	Major Mandatory	Biostatistics	MSU0325MML937J1
2		Time Series Analysis	MSU0325MML937J2
3		Practical-IV	MSU0325MMP937J3
4	Major Elective*	Optimization Techniques	MSU0325MEL937J1
5		Statistical Quality Control	MSU0325MEL937J2
6		Spatial Data Analysis	MSU0325MEL937J3
7		Actuarial Statistics	MSU0325MEL937J4
8	Research Project	Research Project	MSU0325RPP937J

*Only one course under this category is to be chosen by the student.

M. Sc. Statistics (Part II) (Level-6.5) (Semester III) (NEP-2020)

Title of Course: Stochastic Processes
Course Code: MSU0325MML937I1
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Identify appropriate stochastic process model for a given real life process.
2. Specify a given discrete time Markov chain in terms of a transition probability matrix and a transition diagram, and calculate higher step transition probabilities and limiting probabilities.
3. Understand and analyses discrete state space continuous time Markov chains and their practical applications
4. Explore the Galton-Watson Binary Branching process and understand the fundamental elements of Queuing models

Unit 1: Definition of stochastic process, classification of stochastic processes according to state space and time domain, finite dimensional distributions. Examples of various stochastic processes. Definition of Markov chain. Examples of Markov chains, Formulation of Markov chain models, initial distribution, transition probability matrix, Chapman-Kolmogorov equations, calculation of n-step transition probabilities. Simulation of Markov Chain.

(12L +3T)

Unit 2: Classification of states, irreducible Markov chain, period of the state, random walk and gambler's ruin problem, first entrance theorem, first passage time distribution. Long-Run proportions and limiting probabilities, relation with mean recurrence time, stationary distribution.

(12L +3T)

Unit 3: Discrete state space continuous time Markov chain, Poisson process and related results. Birth and death processes and associated cases. Renewal and delayed renewal processes, related theorems, key renewal theorem (Without proof) and its application. Simulation of Poisson process and discrete state space Markov processes.

(12L +3T)

Unit 4: Galton-Watson Binaymi Branching process. Generating functions and its properties, moments. Probability of ultimate extinction. Distribution of population size and association results. Simulation of branching process. Basic elements of Queuing model. Steady state probabilities and various average characteristics for the models: M/M/1, M/M/1 with balking, M/M/c and M/G/1.

(12 L+ 3T)

References:

1. Bhat B. R. (2000). Stochastic Models: Analysis and Applications, (New Age International)
2. Cinlar E. (2013): Introduction to Stochastic Process. (Courier Corporation)
3. Feller W.(2008): An Introduction to Probability Theory and Its Applications. (Wiley)
4. Hoel P. G., Port S. C. and Stone C. J. (1987): Introduction to Stochastic Processes. (Waveland Press)
5. Karlin S. and Taylor H. M. (1968): A First Course in Stochastic Process. (Academic Press)
6. Medhi J. (2009): Stochastic Process, (New Age International Publications)
7. Ross S. (1996): Stochastic Processes. (Wiley)
8. Ross S. (2014): Introduction to Probability Models. (Academic Press)
9. Taylor H. M. and Karlin S. (2014): An Introduction to Stochastic Modeling (Academic Press)

Title of Course: Theory and Practice of Machine Learning
Course Code: MSU0325MML937I2
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Explain supervised learning and construct classifiers namely, decision tree, k-nearest neighbour(s), logistic regression, naïve Bayes, Bayesian Belief Network
2. Compare different classifiers and employ techniques to improve their performance.
3. Use Artificial Neural Network and Support Vector Machine for classification and prediction.
4. Apply clustering techniques and generate association rules using apriori algorithm.

Unit 1: 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.

(12L+3T)

Unit 2: 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 AdaBoost, Random Forests, Improving Classification Accuracy of Class-Imbalanced Data.

(12L+3T)

Unit 3: ANN and SVM: Artificial Neutral Network (ANN): Introduction to ANN, types of activation functions: identity, sigmoid, double sigmoid, tanh, softmax, loss functions: squared error, cross entropy; optimizers: gradient decent, stochastic and minibatch gradient decent; McCulloch-Pitts AN model, single layer network, multilayer feed forward network model, training methods, ANN & regression models. 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.

(12L+3T)

Unit 4: Unsupervised learning: Clustering: k-mediods, CLARA, DENCLUE, DBSCAN, Probabilistic model based clustering. Market Basket Analysis: Association rules and prediction, Apriori Algorithm, data attributes, applications to electronic commerce.

(12L+3T)

References:

1. Berson and Smith S.J. (1997) : Data warehousing, Data Mining, and OLAP, McGraw-Hill.
2. Breiman J.H Friedman, R.A. Olshen and stone C.J. (1984) : Classification and Regression Trees, Wadsworth and Brooks / Cole.
3. Han, J. and Kamber, M. and Pei, J. (2012) : Data Mining: Concepts and Techniques. MorganGaufmann.3rd Edition.
4. Mitchell T.M. (1997) : Machine Learning , McGraw-Hill.
5. Ripley B.D. (1996) : Pattern Recognition and Neural Networks. Cambridge University Press.
6. Vapnik V.N. The nature of Statistical learning theory, Springer.
7. Cristianini N. and Shawe-Taylor J. An Introduction to support vectormachines.
8. Data set source: http://www.ICS.uci.edu/~mlearn/MLRepository.html
9. Mehrika, K., Mohan, C., and Ranka (1997) Elements of Artificial neural networks. Penram international.
10. Hastie T, Tibshirani R, Friedmant J, (2009): The elements of statistical Learning, Springer.
11. Chattamvelli, R. (2015). Data mining methods. Alpha Science International.

Title of Course: Multivariate Analysis
Course Code: MSU0325MML937I3
Total Credits: 02
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Perform exploratory multivariate data analysis, understand and apply discrimination and classification techniques and apply hierarchical and non-hierarchical clustering techniques
2. Understand and apply the Canonical Correlation Analysis, principal component analysis and factor analysis.

Unit 1: Exploratory multivariate data analysis, sample mean vector, sample dispersion matrix, correlation matrix, graphical representation, Partial and multiple correlation coefficients. 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 discriminant function, classification with three populations. Cluster analysis, Hierarchical methods: Single, Complete, average linkage method and non-hierarchical clustering method: k-means clustering.

(12L+3T)

Unit 2: Canonical correlation analysis: Introduction, canonical variates and canonical correlation, interpreting population canonical variables, sample canonical variates and sample canonical correlations; Principal component analysis: Introduction, Population principal components, summarizing sample variation by principal components, Graphing the principal components, large sample inferences; Factor analysis: Introduction, Orthogonal factor model, methods of estimation, factor rotation and factor score

(12L+3T)

References:

1. Kshirsagar A. M.(1972) : Multivariate Analysis. Marcel-Dekker.
2. Johnson, R.A. and Wichern . D.W (2002) : Applied multivariate Analysis. 5th Ad.Prentice – Hall.
3. Anderson T. W. (1984) : An introduction to Multivariate statistical Analysis 2nd Ed. John Wiely.
4. Morrison D.F. (1976) : Multivariate Statistical Methods McGraw-Hill.
5. Bhuyan K. C. (2005): Multivariate Analysis and its applications, New central book agency Ltd. Kolkatta.

Title of Course: Design and Analysis of Experiments
Course Code: MSU0325MEL937I1
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Explain the fundamentals of experimental design.
2. Design and analyze a general full factorial experiment with more emphasis on two-level and three-level full factorial experiments.
3. Design and analyze two-level and three-level fractional factorial experiments.
4. Implement advanced experimental techniques such as Response Surface Methodology and Robust Parameter Design.

Unit 1: Concept of design of experiments (DOE), applications of DOE; Basic principles of DOE; Analysis of completely randomized design using the fixed effect model and estimation of the model parameters; Contrasts, orthogonal contrasts, Scheffé's method for comparing contrasts; Comparing pairs of treatment means: Tukey's test, Fisher least significant difference method; Analyses of randomized complete block design, Latin square design, balanced incomplete block design using fixed effect models and estimation of the model parameters.

(12L+3T)

Unit 2: Concepts of factorial designs; The general factorial design; The two-factor factorial design and its analysis using fixed effect model: main effects, and interaction effects, Analysis of replicated and unreplicated 2^k full factorial designs; Blocking and confounding in a 2^k factorial design. Construction and analysis of 2^{k-p} fractional factorial designs and their alias structures; Design resolution, resolution III and resolution IV designs; fold over designs.

(12L+3T)

Unit 3: The 3^k full factorial design and its analysis using fixed effect model; Confounding in3^k factorial designs; Construction and analysis of 3^{k-p} fractional factorial designs and their alias structures; Concept of random effects and mixed effects models, analysis of 2^k factorial designs using the random effect model, analysis of 2^k factorial designs using the mixed effect model, rules for expected mean squares, approximate F-tests.

(12L+3T)

Unit4: Response surface methodology: the method of steepest ascent, analysis of the response surface using first and second order models, characterizing the response surface, multiple responses, designs for fitting response surfaces: simplex design, central composite design (CCD), spherical CCD,; Robust parameter design: crossed array designs and their analyses, combined array designs and the response model approach.

(12L+3T)

References:

1. Dean, A., & Voss, D. (Eds.). (1999). *Design and analysis of experiments*. New York, NY: Springer New York.
2. Montgomery D.C. (2017): *Design and Analysis of Experiments*, 9th edition, John Wiley & Sons,Inc.
3. Phadke, M.S.(1995). *Quality Engineering using Robust Design*, Prentice-Hall.
4. Wu, C.J., and Hamada, M.S.(2000).*Experiments: Planning, Analysis and Parameter Design Optimization, 2nd edition*, John Wiley & Sons.

Title of Course: Econometrics
Course Code: MSU0325MEL937I2
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Explain fundamentals of Econometrics.
2. Address heteroscedasticity in econometric data.
3. Acquire competency in simultaneous equations modeling.
4. Apply econometric methods in Real-World Scenarios.

Unit 1: Introduction: Definition and scope of econometrics, Methodology of econometrics. Nature and source of Data for econometric analysis, Types of data: cross section, time series, panel data, dummy variable, instrumental variable. Basic concepts of estimation: Review of general linear model, Ordinary least squares, generalized least squares.

(12L+ 3T)

Unit 2: Heteroscedasticity: consequences and tests: White test, Goldfeld-Quandt test; Estimation: estimation with grouping of observations, estimation of the heteroscedasticity relation. Linear regression with stochastic regressors, Instrumental variable estimation, Errors in variables. Autocorrelation, Autoregressive linear regression, Distributed lag models.

(12L+ 3T)

Unit 3: Simultaneous linear equations model. Example, Identification problem, Restrictions on structural parameters-rank and order conditions. Estimation in simultaneous equations model. Recursive systems. Two-Stage Least Squares estimators. Limited information estimators.

(12L+ 3T)

Unit 4: Definition of causality, Granger causality, Granger test for causality. Application of econometric methods: estimation of demand and supply function – production and cost function, consumption and investment functions.

(12L+ 3T)

References:

1. Apte, P.G. (1990): Text book of Econometrics. Tata McGraw Hill.
2. Gujarati, D.N. (2003): Basic Econometrics, McGraw Hill.
3. Johnston, J. (2006). Econometric Methods, third edition, McGraw Hill
4. Marno Verbeek, (2012): A guide to Modern Econometrics, 4/e,Wiley and Sons.
5. Nachane, D. M. (2006). Econometrics: Theoretical Foundations and Empirical Perspective, Oxford University Press
6. Ramanathan, R. (2002). Introductory Econometrics with applications, 5/e, Thomson Asia Private Limited
7. Wooldridge, J. (2012). Introductory Econometrics: A Modern Approach, 5/e, South- Western.

Title of Course: Functional Data Analysis
Course Code: MSU0325MEL937I3
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Understand the concept of functional data and provide their summary statistics.
2. Perform Smoothing of Functional Data by Least Squares.
3. Perform Tests of hypotheses related to mean and covariance Functions.
4. Perform Principal Components Analysis and Canonical Correlation Analysis for Functional Data.

Unit1: Introduction to functional data, Summary statistics for functional data. Functional means and variances; Covariance and correlation functions; Cross-covariance and cross-correlation functions; Representing functions by basis functions; illustration with real data with R.

(12L + 2T)

Unit 2: Smoothing functional data by least squares, illustration with real data with R. various data depths for Functional data, Visualization of functional data using bag plots, rainbow plots and box-plots. Outlier detection. illustration with real data with R.

(12L + 2T)

Unit 3: Test for Equality of two mean functions, Test for Equality of two covariance functions, One way functional ANOVA; computation (without any proofs) and application to real data using R.

(12L + 2T)

Unit 4: Principal components analysis for functional data, Canonical correlation analysis for functional data; concept, computation (without any proofs) and illustration with real data using R.

(12L + 2T)

References:

1. Ramsay, James O., and Bernard W. Silverman. Functional data analysis,. Springer, 2005.
2. Ramsay, James O., and Bernard W. Silverman. Applied functional data analysis: methods and case studies. Springer, 2007.
3. Horváth, Lajos, and Piotr Kokoszka. Inference for functional data with applications. Springer Science & Business Media, 2012.

Title of Course: Practical III
Course Code: MSU0325MMP937I4
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Perform computations related to stochastic processes.
2. Study various stochastic processes through simulation.
3. Apply machine learning techniques to real data sets.
4. Analyze multivariate data using statistical software.

List of the practicals:

1. Simulation of Markov Chain
2. Computations on Markov Chain
3. Classification of Markov Chain
4. Stationary distribution of Markov Chain and its applications
5. Simulation of discrete time continuous state space stochastic processes
6. Supervised learning: Classification
7. Supervised learning: Prediction
8. Artificial neural network
9. Unsupervised learning
10. Association rule mining
11. Exploratory Multivaraite Data Analysis
12. Application of Discriminant Analysis and Cluster Analysis
13. Application of Principal Component Analysis
14. Application of Factor Analysis
15. Application of canonical correlation Analysis

16-20: five practicals on the elective course

M. Sc. Statistics (Part II) (Level-6.5) (Semester IV) (NEP-2020)

Title of Course: Biostatistics
Course Code: MSU0325MML937J1
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Explain the need, ethics, and various concepts in clinical trials.
2. Design and perform various phases of clinical trials.
3. Analyze Phase I-III bio-equivalence trials, case-control and cohort designs.
4. Explain the concept of censoring, various types of censoring, and perform inference about survival function.

Unit 1: Introduction to clinical trials: aim, need and ethics of clinical trials, conduct of clinical trials, preclinical research, phase I-IV trials, multi-center trials, bias and random error in clinical studies, randomization, blinding/masking in clinical trials, data management: data definitions, case report forms, database design, data collection systems for good clinical practice.

(12L+3T)

Unit 2: Design of clinical trials: parallel vs. cross-over designs, cross-sectional vs. longitudinal designs, factorial designs, objectives and endpoints of clinical trials, design of Phase I trials, design of single-stage and multi-stage Phase II trials, design, and monitoring of Phase III trials with sequential stopping.

(12L+3T)

Unit 3: Bioavailability, pharmacokinetics, and pharmaco-dynamics. Design of bio-equivalence trials, Decision rules for bioequivalence, Inference for 2x2 crossover design: Classical methods of interval hypothesis testing for bioequivalence, Bayesian methods, nonparametric methods, assessment of Inter-and Intra-subject variability, drug interaction studies, reporting and analysis: analysis of categorical outcomes from Phase I - III trials. Epidemiological studies: case-control and cohort study designs. Measures of disease occurrence and association.

(12L+3T)

Unit 4: Introduction to survival analysis, examples of survival data/time to event data, measurement of survival time, concept of censoring, various types of censoring, type-I, type-II, random censoring, likelihood constructions and ML estimation. Non parametric estimation of survival function: Actuarial Estimator, Kaplan Meier product limit estimator, non parametric estimates of the mean, median and percentiles of the survival times; Nelson Aalen estimator, non parametric tests for two-sample problem: Gehen test, Log rank test, Mantel Haenszel test. Cox proportional hazard regression model.

(12L + 2T)

References:

1. Chow, S. C., & Liu, J. P. (2008). *Design and analysis of clinical trials: concepts and methodologies* (Vol. 507). John Wiley & Sons.
2. Clayton, D., & Hills, M. (2013). *Statistical models in epidemiology*. OUP Oxford.
3. Collett, D. (2023). *Modelling survival data in medical research*. CRC press.
4. Daniel, W. W., & Cross, C. L. (2018). *Biostatistics: a foundation for analysis in the health sciences*. Wiley.
5. Deshpande, J. V., & Purohit, S. G. (2015). *Lifetime Data: Statistical Models and Methods* (Vol. 16). World Scientific Publishing Company.
6. Fleiss, J. L. (2011). *Design and analysis of clinical experiments*. John Wiley & Sons.
7. Friedman, L. M., Furberg, C. D., DeMets, D. L., Reboussin, D. M., & Granger, C. B. (2015). *Fundamentals of clinical trials*. springer.
8. Hosmer Jr, D. W., Lemeshow, S., & May, S. (2011). *Applied survival analysis: regression modeling of time-to-event data*. John Wiley & Sons.

9. Jennison, C., & Turnbull, B. W. (1999). *Group sequential methods with applications to clinical trials*. CRC Press.
10. Marubeni .E. and Valsecchi M. G. (1994). *Analyzing Survival Data from Clinical Trials and Observational Studies*. Wiley.
11. Miller R. G. (1981). *Survival Analysis*, McFraw-Hill, New York.
12. Piantadosi, S. (2017). *Clinical trials: a methodologic perspective*. John Wiley & Sons.

Title of Course: Time Series Analysis
Course Code: MSU0325MML937J2
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Understand the time series; understand the concept of stationarity to the analysis of time series data in various contexts (such as actuarial studies, climatology, economics, finance, geography, meteorology, political science, and sociology).
2. Identify and isolate non deterministic components of observed time series; learn to translate an observed non-stationary series to stationary time series using an appropriate transformation.
3. Model, estimate, interpret and forecast observed time series through ARMA, ARIMA and SARIMA approach and Perform residual analysis for checking model adequacy.
4. Learn basics of time dependent volatility in time series, basics of ARCH and GARCH time series heteroscedastic models and basic of multivariate time series and its modeling

Unit 1: Exploratory time series analysis, Exponential, Double exponential and Holt-Winter smoothing and forecasting, auto-covariance, auto-correlation functions and their properties and characterization (without proof), partial auto covariance function, auto-covariance generating function. Weak and strong stationary time series, white noise process, Linear Process, estimates of mean, auto-covariance, auto-correlation and partial auto-covariance functions.

(12 L + 3 T)

Unit 2: Wold representation of linear stationary processes, linear time series models: autoregressive(AR), moving average(MA), autoregressive moving average models (ARMA). causality and invertibility of ARMA processes, computation of π -weights and ψ- weights, computation of ACVF, ACF and PACF for AR(1), AR(2), MA(1), MA(2), ARMA(1,1) processes and general procedure for ARMA(p,q) process. The need for differencing a time series, autoregressive integrated moving average models(ARIMA).

(12 L + 3 T)

Unit 3: Estimation of ARMA models: Yule-Walker estimation for AR Processes, Maximum likelihood and least squares estimation for ARMA Processes, Residual analysis and diagnostic checking. Minimum mean squared error forecasting for ARMA and ARIMA models, updating forecasts. Introduction to SARIMA models, Spectral Representation of the ACVF, Spectral density of an ARMA process, its computation for simple models.

(12 L + 3 T)

Unit 4: Introduction to ARCH and GARCH models. Properties and estimation under ARCH(1) and GARCH(1,1) model. Vector time-series models: Covariance and Correlation Matrix functions, MA and AR representation of vector processes, Covariance matrix function of the vector AR(1) and MA(1) models.

(12L + 3T)

Reference:

1. Box, G. E., Jenkins, G. M., Reinsel, G. C., & Ljung, G. M. (2015). *Time series analysis: forecasting and control*. John Wiley & Sons.
2. Brockwell, P. J., & Davis, R. A. (2009). *Time series: theory and methods*. Springer science & business media.
3. Chatfield, C. (2004) *The Analysis of Time Series - An Introduction*, Sixth edition, Chapman and Hall.
4. Kendall, M.G. (1978) *Time Series*, Charler Graffin
5. Tsay, R. S. (2005). *Analysis of financial time series*. John wiley & sons.
6. WEI, W. W. (2006). *Time Series Analysis: Univariate and Multivariate Methods*.

Title of Course: Optimization Techniques
Course Code: MSU0325MEL937J1
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Formulate a problem as an appropriate optimization problem (LPP, IPP, QPP).
2. Apply various methods to obtain optimum solution of a LPP, IPP and QPP.
3. Solve two person zero sum games with pure and mixed strategies using various methods.
4. Explain, formulate and solve dynamic Programming problem.

Unit 1: Convex Sets and Functions: Convex sets, supporting and separating hyperplanes, convex polyhedra and polytope, extreme points, convex functions. Linear programming problem (LPP): Definition and applications, methods of solving LPP: Graphical method, Simplex method, theorems related to the development of simplex algorithm, theorems related to a basic feasible solution, reduction of a feasible solution to a basic feasible solution, improvement of a basic feasible solution, existence of unbounded solution, optimality conditions and other related theorems (statements only), Examples. Artificial variable technique: Two phase method, Big M method, degeneracy.

(12L+3T)

Unit 2: Concept of Duality, related theorems, complementary slackness property and development of dual simplex algorithm. Sensitivity Analysis: Changes in the cost vector, requirement vector and non-basic activity vector; addition of new variables and addition of new constraints.

(12L+3T)

Unit 3: Integer Linear Programming Problem (ILPP): The concept of cutting plane, cutting plane method for all ILPP and mixed ILLP, Branch and Bound method. Quadratic programming: Kuhn-Tucker conditions, methods due to Beale, Wolfe.

(12L+3T)

Unit 4: Theory of games: two person zero sum games, minimax and maximin principles, Saddle point, mixed strategies; rules of dominance, solution of 2 x 2 game by algebraic method, Graphical method, Reduction of the game problem as LPP. Dynamic Programming: The Recursion Equation Approach, Computational Procedure, Characteristics of Dynamic Programming, Solution of L.P.P. by Dynamic Programming.

(12L+3T)

References:

1. Hadley G.(1969): Linear Programming, Addison Wesley
2. Taha H. A. (1971): Operation Research: An Introduction, Macmillan N.Y.
3. Kanti Swaroop & Gupta M. M.(1985): Operations Research, Sultan Chand & Co. ltd.
4. P.Gupta & D. S. Hira(2010): Operation Research, Sultan Chand & Co. ltd.
5. J. K. Sharma. (2003): Operation Research: Theory and Applications. Macmillan.

Title of Course: Statistical Quality Control
Course Code: MSU0325MEL937J2
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Explain and apply Quality Improvement Tools and Shewhart Control Charts.
2. Explain and apply Advanced Control Charts.
3. Perform Process Capability Analysis and apply Six Sigma Methodology.
4. Design and apply Acceptance Sampling Plans.

Unit 1: Quality Improvement Tools: affinity diagram, interrelationship digraph, tree diagram, prioritization matrix, matrix diagram, process decision program chart, activity network diagram, Shewhart Control charts: basic statistical principles and assumptions, phase I and phase II applications, concept of rational subgroups, performance measures of a control chart, $\overline{X}$, R, S, p, c and D charts, σ-control limits and probability control limits, Modifications to control chart procedures: warning limits, sensitizing rules, adaptive design parameters, Engineering Process Control.

(12L+3T)

Unit 2: Alternatives to Shewhart control charts for process mean: Moving average control chart, CUSUM chart, EWMA charts, combined Shewhart-CUSUM chart, combined Shewhart–EWMA Chart, SPRT chart, and GLR Chart; Nonparametric control charts for process mean; Multivariate Control Charts: multivariate chart versus individual charts, Hotelling's T^2control chart.

(12L+3T)

Unit 3: Process capability Analysis: process capability, process capability indices (C_p, C_{pk}, C_{pm}), point and interval estimation of C_p and C_{pk}; Nonparametric Capability Indices: robust capability indices, capability indices based on fitted distributions and data transformation, capability indices computed using resampling methods. Six Sigma Methodology: components of a Six Sigma methodology, the DIMAC process, Six Sigma training.

(12L+3T)

Unit 4: Acceptance sampling plans for attributes: single sampling plan, double and multiple sampling plans, sequential sampling. Performance measures of sampling plans. Acceptance sampling plans for variables: Advantages and Disadvantages of Variables Sampling, Sampling inspection plans by variables for one or two sided specifications, Sequential Sampling by Variables, Rectifying inspection of lots, the Deming inspection criterion, Continuous sampling plans, skip-lot sampling plans.

(12L+3T)

References:

1. Guenther, W. C. (1977). *Sampling Inspection in statistical quality control*. Macmillan.
2. Kenett, R. S. and Zacks, S. (2021). *Modern industrial statistics: With applications in R, MINITAB and JMP*. John Wiley & Sons.
3. Montgomery, D. C. (2010). *Statistical Quality Control: A Modern Introduction*, 6th Edition. Wiley India Pvt Ltd.
4. Ryan, T. P. (2011). *Statistical methods for quality improvement*. John Wiley & Sons.

Title of Course: Spatial Data Analysis
Course Code: MSU0325MEL937J3
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Explain Fundamentals of Spatial Data Analysis.
2. Acquire expertise in Spatial Sampling and Data Pre-processing.
3. Perform Regression Modelling for Spatial Data.
4. Perform Analysis of Spatiotemporal Data.

Unit 1: Spatial data and their types, the components of spatial data, spatial data models, spatial autocorrelation, modeling spatial autocorrelation, measures of spatial autocorrelation, tests for spatial autocorrelation, a spatial random process and its components.

(12L + 3T)

Unit 2: Spatial sampling: design-based and model-based approaches to spatial sampling, sampling plans. Preprocessing of spatial data: quality of attribute data, spatial interpolation procedures, spatial rectification and alignment of data, Exploratory spatial data analysis.

(12L + 3T)

Unit 3: Regression models for spatially autocorrelated data: Detecting spatial autocorrelation in a regression model, Models for spatial processes: the spatial lag model and the spatial error model, Determining the appropriate regression model, Fitting the spatial lag and spatial error models, The conditional autoregressive model

(12L + 3T)

Unit 4: Analysis of spatiotemporal data: Spatiotemporal data interpolation, representing spatiotemporal data, the spatiotemporal variogram, interpolating spatiotemporal data, spatiotemporal process models, finite state and time models.

(12L + 3T)

References:

1. Bivand, R. S., Pebesma, E. J., Gomez-Rubio, V., & Pebesma, E. J. (2008). *Applied spatial data analysis with R*, second edition. New York: Springer.
2. Fischer, M. M., & Wang, J. (2011). *Spatial data analysis: models, methods and techniques*. Springer Science & Business Media.
3. Haining, R. P. (2003). *Spatial data analysis: theory and practice*. Cambridge University Press.
4. Plant, R. E. (2018). *Spatial data analysis in ecology and agriculture using R*, second edition. CRC Press.

Title of Course: Actuarial Statistics
Course Code: MSU0325MEL937J4
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Understand Insurance Business, Insurance and Utility Theory, Risk Models for Insurance.
2. Calculate quantities such as premiums, reserves and superannuation contribution rates using actuarial technique
3. Analyze various types of annuities, including annuities certain, continuous and discrete life annuities.
4. Expand their applied knowledge in various specialized areas of actuarial studies and statistics.

Unit-1: Introduction to Insurance Business, Insurance and utility theory, 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.

(12L+3T)

Unit-2: 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, accumulation factor, continuous compounding. Insurance payable at the moment of death and at the end of the year of death, level benefit insurance, Whole life insurance, endowment insurance, deferred insurance and varying benefit insurance. Recursion equations and commutation functions.

(12L+3T)

Unit-3: Annuities: Annuities certain, Continuous and Discrete life annuities. Life annuities with monthly payments and approtionable annuities. Recursion equations. Net premium: Fully continuous and discrete premiums, True monthly payment premiums, apportionable premiums and accumulation type benefits. Insurance model including expenses.

(12L+3T)

Unit-4: Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi continuous basis, reserves based on true monthly premiums, reserves on an apportion able or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.
Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss Insurance.

(12L+3T)

References:

1. Robin Cunningham, Thomas N. Herzog, Richard L. Models for Quantifying Risk, 4th Edition, ACTEX Publications, 2011.
2. Browers, Newton L et al., Actuarial Mathematics 2nd . Society of Actuaries, 1997.
3. Dickson, David C. M., Hardy, Mary R. and Waters, Howard R., Actuarial Mathematics for life contingent risks, International series on actuarial science, Cambridge 2009.
4. Deshmukh S. R., An Introduction to Actuarial Statistics, University Press, 2009
5. Narang, Uma, Insurance Industry in India: Features, Reforms and Outlook, New Century Publications

Title of Course: Practical IV
Course Code: MSU0325MMP937J3
Total Credits: 04
Course outcomes:
Upon successful completion of this course, the students will be able to:

1. Analyze data generated in clinical trials.
2. Perform parametric and non-parametric analysis of survival data.
3. Model and analyze various time series data.
4. Use statistical software for analysis.

List of practicals

1. Pharmacokinetic Parameters
2. Statistical Methods for Bioequivalence
3. Epidemiology
4. Parametric Analysis of Survival Data
5. Non parametric analysis of survival data
6. Cox-proportional hazard model
7. Exploratory analysis of time series data
8. smoothing time series data and forecasting
9. Modeling and analysis of univariate time series.
10. Modeling and analysis of Heteroscedastic time series.
11. Modeling and analysis of time series.

12-16: five practicals on the elective course

Equivalence of courses

M. Sc. Part II (Semester III and IV)

Old Course				Equivalent Course		
Sem. No.	**Course Code**	**Title of Old Course**	**Credit**	**Course code**	**Title of New Course**	**Credit**
III	CC-301	Asymptotic Inference	4	No equivalence can be given for these courses in the new syllabus as per NEP 2020		
III	CCS-302	Multivariate Analysis	4			
III	CCS-302	Bayesian Inference	4			
III	CCS-303	Stochastic Processes	4	MSU0325MML937I1	Stochastic Processes	4
III	CCS-303	Functional Data Analysis	4	MSU0325MEL937I3	Functional Data Analysis	4
III	CCS-304	Data Mining	4	MSU0325MML937I2	Theory and Practice of Machine Learning	4
III	CCS-304	Artificial Intelligence	4	No equivalence can be given for these courses in the new syllabus as per NEP 2020		
III	DSE-305	Time series analysis	4	MSU0325MML937J2	Time series analysis	4
III	DSE-305	Statistical ecology	4	No equivalence can be given for these courses in the new syllabus as per NEP 2020		
III	CCPR-306	Practical III	4	MSU0325MMP937I4	Practical III	4
IV	CC-401	Generalized Linear Model	4	No equivalence can be given for these courses in the new syllabus as per NEP 2020		
IV	CCS-402	Survival Analysis	4			
IV	CCS-402	Actuarial Statistics	4	MSU0325MEL937J4	Actuarial Statistics	4
IV	CCS-403	Biostatistics	4	MSU0325MML937J1	Biostatistics	4
IV	CCS-403	Econometrics	4	MSU0325MEL937I2	Econometrics	4
IV	CCS-404	Optimization Techniques	4	MSU0325MEL937J1	Optimization Techniques	4
IV	CCS-404	Circular Data Analysis	4	No equivalence can be given for these courses in the new syllabus as per NEP 2020		
IV	DSE-405	Spatial data Analysis	4	MSU0325MEL937J3	Spatial data Analysis	4
IV	DSE-405	Statistical Quality Control	4	MSU0325MEL937J2	Statistical Quality Control	4
IV	CCPR-406	Practical IV and Project	4	MSU0325MMP937J3	Practical IV	4

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