YEAR 4: SEMESTER **VII**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-7.1-T	Real Analysis	Major	6	6	10	5	40	20	75
ST-M-7.2-T	Measure Theory and Probability	Major	6	4	15	-	60	-	75
ST-M-7.3-P	R Programming (Prac)	Major	6	3		15		60	75
ST-MI-7.1-T ST-MI-7.1-P	Applied Statistics (Theo & Prac)	Minor	3+1=4	3	7	3	28	12	50
ST-MI-7.2-T	Sampling Distribution (Theo)	Minor	3+1=4	4	10	-	40	-	50
Total			26	26	65		260		325

YEAR 4: SEMESTER **VIII**

Course Code	Course Title	Course Type	Credit	Class hour/ week	Marks				Total Marks
					Internal		End-Sem		
					Th	Pr	Th	Pr	
ST-M-8.1-T ST-M-8.1-P	Stochastic Process (Theo & Prac)	Major	3+1=4	4	7	3	28	12	50
ST-M-8.2-T ST-M-8.2-P	Machine Learning (Theo & Prac)	Major	3+1=4	4	7	3	28	12	50
ST-M-8.3-T ST-M-8.3-P	Econometrics and Time Series (Theo & Prac)	Major	3+1=4	4	7	3	28	12	50
ST-M-8.4-T* ST-M-8.4-P*	Operations Research (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-M-8.5-T* ST-M-8.5-P*	Survival Analysis (Theo & Prac)	Major	4+2=6	6	10	5	40	20	75
ST-SI-8#	Summer Internship	Project/ Dissertation	12	12					
Total			24	24					

*For Honours without Research

#For Honours with Research

5. Chatfield, C.: The Analysis of Time Series – An Introduction, Chapman & Hall.
6. Allen, R. G. D.: Index Numbers in Theory and Practice, Macmillan.
7. Brockwell, P. J. & Davis, R. A.: Introduction to Time Series and Forecasting, SpringerVerlag.

YEAR 4: SEMESTER VII

Paper: ST-M-7.1-T Real Analysis (Theoretical) Course Type: Major
Credit 6 Marks 75

Unit 1

Introduction to real number, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass theorem, Heine-Borel theorem. (12L)

Unit 2

Real valued functions. Limit, continuity and uniform continuity, Differentiability of univariate and multivariate functions. Mean value Theorems, Extrema of functions. (12L)

Unit 3

Riemann Integral. Improper integrals. Riemann – Stieltjes integral. Sequence and series of functions, uniform convergence, Power series. (10L)

Unit 4

Convex functions and related properties. (5L)

Suggested Reading:

1. Apostol, T.M. (1985): Mathematical Analysis, Narosa.

2. Rudin, W. (1976): Principles of Mathematical Analysis, McGraw Hill.

3. Goldberg, R.R.: Methods of Real Analysis.

Paper: ST-M-7.2-T Measure Theory and Probability (Theoretical)

Course Type: Major Credit 6 Marks 75

Unit 1

Classes of sets, Fields, Sigma fields, Minimum Sigma field, Borel Sigma field in R, Sequence of sets, limsup and liminf of a sequence of sets. Measure, Probability Measure, Properties of a measure. (10L)

Unit 2

Measurable functions, Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated Convergence Theorem. (8L)

Unit 3

Random variables, D.F., decomposition of D.F., Statement of correspondence theorem, Generating function and Characteristic function, Inversion theorem, Continuity theorem. (statement only) (6L)

Unit 4

Sequence of random variables, Almost sure convergence.

Borel-Cantelli lemma, Independence, Hajek-Reyni inequality, Kolmogorov inequality, strong law of large numbers.

Central Limit Theorem for iid random variables, CLT for a sequence of independent Random variables. Statements of Lindeberg-Feller & Liapounoff's theorem. (12L)

Suggested Reading:

1. A.K. Basu: Measure Theory & Probability.
2. B.R. Bhat: Modern Probability Theory.
3. P. Billingsley: Probability & Measure.
4. J.F.C. Kingman & S.J. Taylor: Introduction to Measure and Probability.
5. R.G. Laha & V.K. Rohatgi : Probability Theory.
6. R. Ash: Real Analysis and Probability.
7. C.W. Burrill: Measure Theory & Probability
8. H. Cramer: Mathematical Statistics.
9. C.R.Rao: Linear Statistical Inference and its Applications.
10. Bartle: The Elements of Integration.
11. K.R. Parthasarathy: Introduction to Probability and Measure.

Paper: ST-M-7.3-P R Programming (Practical) Course Type: Major
Credit 6 Marks 75

Basics of R programming; numerical arithmetic, simple manipulation of vectors, descriptive statistics on univariate data.

Bivariate data, factors, descriptive statistics.

Arrays and matrices, matrix operations.

Lists and data frames, *attach, detach, read.table, scan*; accessing data sets from other R packages.

Probability distributions, Q-Q plots, K-S tests, one and two sample tests.

Grouped expressions, conditional statements, loops, for and while.

Functions in R; named arguments and defaults, assignments within functions, dropping names

in a printed array, scope and class of objects, generic functions and object orientation.

Statistical models in R; Formulae for statistical models, linear model generic functions for extracting model information, ANOVA, updating fitted models, GLM, NLS, maximum likelihood models.

Graphical procedures, high level and low level plotting commands, graphical parameters.

Standard packages from R; some nonstandard statistical models. (30L)

Suggested Reading:

An Introduction to R; manual from www.r-project.org

Papers: ST-MI-7.1-T and ST-MI-7.1-P

Same as ST-MI-5.1-T and ST-MI-5.1-P

Papers: ST-MI-7.2-T

Same as ST-MI-5.2-T

YEAR 4: SEMESTER VIII

Paper: ST-M-8.1 -T Stochastic Process (Theoretical) Course Type: Major
Credit 3 Marks 35

Unit 1

Introduction to Stochastic processes, classification of Stochastic processes according to state space and time domain, Markov chain with finite and countable state space, n-step transition probability and its limit, Chapman – Kolmogorov equation, Stationary distribution, classification of states, Random Walk and gambler's ruin problem. (20L)

Unit 2

Discrete state space continuous time Markov chain: Poisson process, birth and death process.

Renewal Theory: Elementary renewal theory, statement and uses of key renewal theorem.

Branching process: Galton – Watson branching process, probability of ultimate extinction.

Continuous process: Brownian motion. (16L)

Paper: ST-M-8.1 -P Stochastic Process (Practical) Course Type: Major
Credit 1 Marks 15

List of Practical:

1. Problems on Markov Chains
2. Problems on Random Walk
3. Problems on Gambler's ruin

4. Problems on Poisson Process
5. Problems on Branching Processes

Suggested Reading:

1. J. Medhi: Stochastic Processes.
2. S.M. Ross: Introduction to Probability Models.
3. Karlin and Taylor: A First Course in Stochastic Processes.
4. B.R. Bhat: Stochastic Models.

Paper: ST-M-8.2 –T Machine Learning (Theoretical) Course Type: Major
Credit 3 Marks 35

Unit 1

Introduction to Machine Learning: Definition and types of machine learning, Overview of machine learning workflow, Introduction to popular machine learning libraries and tools. (10L)

Unit 2

Supervised Learning: Linear regression, Logistic regression, Decision trees, Random Forests, Support Vector Machines.

Unsupervised Learning: K-means clustering, Hierarchical clustering, Principal component analysis (PCA). (10L)

Unit 3

Neural Networks: Introduction to neural networks, Multilayer perceptrons, Convolutional neural networks (CNNs). (12L)

Unit 4

Model Evaluation and Selection: Metrics for evaluating machine learning models, Cross-validation, Model selection. (12L)

Paper: ST-M-8.2 –T Machine Learning (Practical) Course Type: Major
Credit 1 Marks 15

List of Practical:

1. Use of R Libraries for application problems of Unit 2

2. Use of R Libraries for application problems of Unit 3
3. Use of R Libraries for application problems of Unit 4

Suggested Reading:

1. Andrew Ng and Michael I. Jordan: Machine Learning
2. Gareth James, Daniela Witten, Trevor Hastie, and Robert Tibshirani: An Introduction to Statistical Learning.
3. Michael Nielsen: Neural Networks and Deep Learning.

Paper: ST-M-8.3 –T Econometrics and Time Series (Theoretical) Course Type: Major Credit 3 Marks 35

Unit 1

Nature of Econometrics. Classical General Linear Regression Model (CLRM): Specification, Estimation, Testing, and Interval Estimation. Small and Large Sample Properties of OLS estimators. The problem of multi-collinearity (MC): Effect of exact and near-exact MC estimation and testing of regression parameters. Dummy variable regression and its use in determination of seasonality. Regression Diagnostics. Simultaneous equation models: identification and estimation. (12L)

Unit 2

CLRM with non-spherical disturbance. GLS technique. Aitkin's theorem. Heteroscaedastic disturbance: Consequence on OLS estimation. Tests for heteroscaedasticity. Estimation and testing in CLRM with heteroscaedastic disturbance. (10L)

Unit 3

Smoothing of time series using filters. Representation of time series as a stochastic process. Weakly and strongly stationary processes and their examples. Autocorrelation and partial autocorrelation functions and their properties. (10L)

Unit 4

AR, MA, ARMA models and their properties. Identification, estimation and diagnostic checking of ARMA models. Forecasting. (10L)

Paper: ST-M-8.3 –P Econometrics and Time Series (Practical) Course Type: Major

Credit 1 Marks 15

1. OLS estimation
2. Testing regression parameters
3. Simultaneous equation models
4. Tests for heteroscaedasticity
5. Autocorrelated models
6. Problems relating to AR, MA and ARMA models.

Suggested Reading:

1. W.H. Greene (2002): Econometric Analysis.
2. Mittlehammer, C.R., G.G. Judge, D Miller (2001): Econometric Foundations, Cambridge.
3. Johnston & Dinardo (1990): Econometric Methods, McGraw Hill.
4. Judge, L. et al.: Theory and Practice of Econometrics.
5. Malinvaud, E. (1966): Theory of Econometrics.
6. Theil, H. (1982): Introduction to the Theory and Practice of Econometrics.

Paper: ST-M-8.4-T* Operations Research (Theoretical) Course Type: Major

Credit 4 Marks 50

Unit 1

Definition and scope of OR, Phases in OR. (4L)

Unit 2

Review of Linear Programming Problem, methods of solution, duality in LPP, transportation and assignment problem with proofs of relevant results, traveling salesman problem. (12L)

Unit 3

Inventory models, costs and distributions, EOQ model including the case with price break-ups.
Queuing models – M/M/1: (∞/FIFO) ; M/M/C : ((∞/FIFO) ; M/M/1 : (N/FIFO) models.
Sequencing models, Sequencing n jobs on two machines. (12L)

Unit 4

Elements of game theory two – person games, pure and mixed strategies, existence of solution and uniqueness of value in zero –sum games, finding solutions in 2x2, 2xm and mxn games.

Introduction to networks, determination of floats and critical paths, CPM & PERT. (12L)

Paper: ST-M-8.4-P* Operations Research (Practical) Course Type: Major

Credit 2 Marks 25

List of Practical:

Simple problems related to Unit 2 to Unit 4

Suggested Reading:

1. Goel and Mittal: Operations Research, Sultan Chand.
2. Kanti Swarup, P.K. Gupata & M.M. Singh (1985): Operations Research, Sultan Chand.
3. Philips, D.T., Ravindran, A. and Solberg, J: Operations Research, Principles and Practices.
4. Taha, H.A.: Operations Research: An Introduction, 6th Ed. 1997 Prentice–Hall of India.

Paper: ST-M-8.5-T* Survival Analysis (Theoretical) Course Type: Major

Credit 4 Marks 50

Unit 1

Survival Analysis: Functions of survival times, survival distributions and their applications: exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function. (10L)

Unit 2

Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Non-parametric methods: Kaplan-Meier method for estimating survival function and variance of the estimator. (12L)

Unit 3

Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood principle and modified minimum Chi-square methods. Theory of independent and dependent risks. (12L)

Unit 4

Stochastic Epidemic Models: Simple epidemic models, general epidemic model definitionand concept (without derivation). Duration of an epidemic. (10L)

Paper: ST-M-8.5-P* Survival Analysis (Practical) Course Type: Major
Credit 2 Marks 25

List of Practical:

1. To estimate survival function
2. To identify type of censoring and to estimate survival time for type I censored data
3. To identify type of censoring and to estimate survival time for type II censored data
4. To identify type of censoring and to estimate survival time for progressively type Icensored data
5. Estimation of mean survival time and variance of the estimator for type I censored data
6. Estimation of mean survival time and variance of the estimator for type II censored data
7. To estimate the survival function and variance of the estimator using Non-parametric techniques with Kaplan-Meier method

Suggested Reading:

1. Lee, E.T. and Wang, J.W. (2003): Statistical Methods for Survival Data Analysis, 3rdEdition, John Wiley and Sons.
2. Kleinbaum, D.G. (1996): Survival Analysis, Springer.