U n i v e r s i t y of K a l y a n i

Department of Statistics

STRUCTURE AND DETAILED SYLLABUS FOR

2-Year M. Sc. Course in Statistics

With Effect From 2017-18

COURSE STRUCTURE

2-Year M. Sc. in Statistics: SEMESTER 1

Paper Code	Paper Name	Weekly Contact Period			Credit	Marks		Exam duration	Total marks
		Th.	Pr.	Total		Internal Assessment	End-semester Exam		
2STAT1.1	Real Analysis	4	-	4	3	12	48	2 hr	60
2STAT1.2	Linear Algebra	2	2	4	2	12	48	2 hr 30 min	60
2STAT1.3	Sampling Distribution	4	-	4	2	12	48	2 hr	60
2STAT1.4	Sample Survey	2	2	4	3	12	48	2 hr 30 min	60
2STAT1.5	Linear Models	2	2	4	2	12	48	2 hr 30 min	60
2STAT1.6	Operations Research	2	2	4	2	12	48	2 hr 30 min	60
2STAT1.7	C++ Programming	-	4	4	2	8	32	Assignment	40
Total		16	12	28	16	80	320		400

2-Year M. Sc. in Statistics: SEMESTER 2

Paper Code	Paper Name	Weekly Contact Period			Credit	Marks		Exam duration	Total marks
		Th.	Pr.	Total		Internal Assessment	End-semester Exam		
2STAT2.0 (Open)	Basics of Probability & Statistics	4	-	4	4	20	80	4 hr	100
2STAT2.1	Probability & Measure Theory	3	-	3	2	12	48	2 hr	60
2STAT2.2	Stochastic Process	2	1	3	2	8	32	2 hr	40
2STAT2.3	Large Sample Theory	2	-	2	2	8	32	1 hr 30 min	40
2STAT2.4	Design of Experiments	3	2	5	3	16	64	3 hr	80
2STAT2.5	Econometrics & Time Series Analysis	3	2	5	3	16	64	3 hr	80
Total		17	5	22	16	80	320		400

2-Year M. Sc. in Statistics: SEMESTER 3

Paper Code	Paper Name	Weekly Contact Period			Credit	Marks		Exam duration	Total marks
		Th.	Pr.	Total		Internal Assessment	End-semester Exam		
2STAT3.1	Estimation Theory	3	2	5	3	14	56	2 hr 30 min	70
2STAT3.2	Testing of Hypothesis	3	2	5	3	14	56	2 hr 30 min	70
2STAT3.3	Nonparametric Methods	3	2	5	3	14	56	2 hr 30 min	70
2STAT3.4	Decision Theory	3	2	5	3	14	56	2 hr 30 min	70
2STAT3.5	SQC and Reliability	2	2	4	2	14	56	2 hr 30 min	70
2STAT3.6	R Programming	-	4	4	2	10	40	Assignment	50
Total		14	14	28	16	80	320		400

2-Year M. Sc. in Statistics: SEMESTER 4

Paper Code	Paper Name	Weekly Contact Period			Credit	Marks		Exam duration	Total marks
		Th.	Pr.	Total		Internal Assessment	End-semester Exam		
2STAT4.1	Special Paper	4	2	6	4	20	80	3 hr 30 min	100
2STAT4.2	Special Paper	4	2	6	4	20	80	3 hr 30 min	100
2STAT4.3	Project				8	40	Dissertation & Presentation: 160		200
Total		8	4	12	16	80	320		400

DETAILED SYLLABUS

2STAT1.1	**Real Analysis (Marks 60, Credit 3)**	**44**
	Introduction to real number, cluster points of sets, closed and open sets, compact sets, Bolzano-Weierstrass theorem, Heine-Borel theorem.	15
	Sequence and series, Convergence. Real valued functions. Limit, continuity and uniform continuity, Differentiability of univariate and multivariate functions. Mean value Theorems, Extreme of functions.	15
	Riemann Integral. Improper integrals. Riemann – Stieltjes integral.	12
	Sequence and series of functions, uniform convergence, Power series.	
	Convex functions and related properties	2

References:

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.

2STAT1.2	**Linear Algebra (Marks 60, Credit 2)**	**40**
	Notion of vector space, n-dimensional vector space, subspaces, union and intersection of subspaces, direct sum, projection in a vector space, Orthogonal projection, Projection operator (finite dimensional).	12
	Idempotent matrix: its properties and use as a projector.	5
	Kronecker product, trace operator and its properties.	2
	Generalized inverse, Moore – Penrose inverse.	5
	Characteristic roots and vectors, Cayley-Hamilton theorem, algebraic	10

	multiplicity, normal matrix, spectral decomposition, singular value decomposition.	
	Simultaneous diagonalisation of two Q. F's., Extrema of Q. F's	6

***References**:*

1. Rao, C.R.: Linear Statistical Inference and its Applications, Wiley.
2. Graybill, F.A.: Matrices with Application in Statistics.
3. Searle, S.R.: Matrix Algebra Useful for Statistics.
4. Hadley, G.: Linear Algebra.
5. Rao, A.R. & Bhimasankaram, P.: Linear Algebra.

2STAT1.3	**Sampling Distribution (Marks 60, Credit 2)**	**40**
	Non-central chi-square, t and F distributions.	6
	Distribution of X'AX.	2
	Fisher-Cochran's Theorem and related results.	5
	Random sampling from $N_p(\mu,\Sigma)$, MLE's of μ and Σ and their stochastic independence.	4
	Central Wishart distribution using Bartlett's decomposition and its properties with proofs.	10
	Distribution of Hotelling's T^2 and Mahalanobis's D^2 with applications.	4
	Distribution of sample multiple correlation coefficient.	3
	Distribution of partial correlation coefficient.	3
	Distribution of regression coefficient vector.	3

References:

1. Rao, C.R.: Linear Statistical Inference and its Applications, Wiley.
2. Anderson, T.W.: Introduction to Multivariate Analysis.
3. Kshirsagar, A.M.: Multivariate Analysis.
4. Srivastava, M.S. and Khatri, C.G.: Introduction to Multivariate Statistics.

2STAT1.4	**Sample Survey (Marks 60, Credit 3)**	**30**
	Concepts of sampling design, sampling scheme and sampling strategy, Horvitz – Thompson method of estimation, mean per distinct unit estimator of population mean with reference to SRSWR with varying probability with and without replacement, Des Raj method of estimation, Murthy's underlying principle and its application in PPS without replacement sampling, symmetrized Des Raj estimator, sampling strategy due to Rao, Hartley and Cochran scheme of sampling.	16
	Sampling on two successive occasions with probability sampling on both.	4
	Nonresponse: Hansen-Horvitz callback method, Politz-Simmons' not-at-home method.	4
	Randomized response techniques – both qualitative and quantitative	6

References:

1. Cochran: Sampling Techniques, Wiley
2. Des Raj.
3. Murthy.
4. Chaudhury & Mukerjee: Randomized Response.
5. Chaudhury & Stenger: Theoty of Statistical Survey Sampling.
6. Sinha & Hedayat.
7. P. Mukherjee.

2STAT1.5	**Linear Models (Marks 60, Credit 2)**	**35**
	Linear models, estimability and BLUE, estimation space and error space, method of least squares, Gauss-Markov theorem, SS due to Linear functions of observations, canonical forms, F-statistic in connection with the general linear hypothesis.	14
	Application of g-inverse and projection operators in connection with	5

	BLUE's and related results.	
	Generalized LS estimation under linear restriction on parameters.	3
	Scheffe's and Tukey's multiple comparison techniques.	3
	Tukey's test for non-additivity, Analysis of covariance in the general setup, nested classification.	10

References:

1. Rao, C.R. Linear Statistical Inference and its Applications.
2. Graybill, F.A.: Linear Models vol. I.
3. Graybill, F.A.: Matrices with applications in Statistics.
4. Kshirsagar, A.M : Linear Models.
5. Searle: Linear Statistical Methods.
6. Joshi, D.D.
7. Chakraborty, M.C.

2STAT1.6	**Operations Research (Marks 60, Credit 2)**	**45**
	Definition and scope of OR, Phases in OR.	2
	Review of Linear Programming Problem, methods of solution, duality in LPP, transportation and assignment problem with proofs of relevant results, traveling salesman problem.	14
	Inventory models, costs and distributions, EOQ model including the case with price break-ups.	6
	Queueing models – M/M/1 : (∞/FIFO) ; M/M/C : ((∞/FIFO) ; M/M/1 : (N/FIFO) models.	7
	Sequencing models, Sequencing n jobs on two machines.	3
	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.	8
	Introduction to networks, determination of floats and critical paths, CPM & PERT.	5

References:

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.

2STAT1.7	**C++ Programming (Marks 40, Credit 2)**	**40**
	Basics of C++ language: Input / Output Statements, Control	40
	Structures.	
	Functions: Library functions, user-defined functions, functions declaration.	
	Pointers: manipulation of pointers data.	
	Applications to some statistical problems.	
	Monte Carlo Simulation.	
	Computer work.	

References:

1. Lafore, R. Object-Oriented Programming in Microsoft C++.

2. Balagurusamy: C++ Programming.

2STAT2.0	**Basics of Probability and Statistics (Marks 100, Credit 4)**	**54**
(Open)	**Descriptive Statistics**: Collection, tabulation and diagrammatic representation of data; Frequency distribution, graphical representation of a frequency distribution, histogram, frequency polygon, ogives; Common measures of central tendency and dispersion, coefficient of variation. Bivariate frequency distribution, scatter diagram, simple correlation and regression.	16
	Probability: Random Experiments, Sample space, Events, classical definition of probability, Theorem of Total probability, Conditional probability, Statistical independence of events, product rule for probability, related problems. Random variables, expectation and variance of random variables, moments and moment generating function, Chebyshev inequality. Binomial, Poisson and Normal distributions, related problems.	18
	Statistical Inference: Population and sample; parameter and statistic, sampling distribution of a statistic, basic concepts of estimation – unbiasedness and consistency, notion of uniformly minimum variance unbiased estimator, standard error. Basic concepts of tests of significance, tests for means of normal distribution, Student's t, Fisher's t and paired t tests, testing equality of means of several normal populations, least significant difference; χ^2 tests for independence in contingency tables. ANOVA for one-way and two-way classified data.	20
2STAT2.1	**Probability and Measure Theory (Marks 60, Credit 2)**	**56**
	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.	15
	Measurable functions, Random variables, D.F., decomposition of D.F., Statement of correspondence theorem, Generating function and	15

	Characteristic function, Inversion theorem, Continuity theorem (statement only)	
	Integration of a measurable function with respect to a measure, Monotone convergence theorem, Fatou's lemma, Dominated Convergence Theorem.	8
	Sequence of random variables, Almost sure convergence.	4
	Borel-Cantelli lemma, Independence, Hajek-Reyni inequality, Kolmogorov inequality, strong law of large numbers.	8
	Central Limit Theorem for iid random variables, CLT for a sequence of independent Random variables. Statements of Lindeberg-Feller & Liapounoff's theorem.	4
	Product measure and Fubini's theorem (Statements only)	2

References:

1. A.K. Basu: Measure Theory & Probability.
2. B.R. Bhat: Modern Probability Theory.
3. P. Billingley: 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. Parthasarathi: Introduction to Probability and Measure.

2STAT2.2	**Stochastic Process (Marks 60, Credit 2)**	**30**
	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	12

	its limit, Chapman – Kolmogorov equation, Stationary distribution classification of states, Random Walk and gambler's ruin problem.	
	Discrete state space continuous time Markov chain: Poisson process, birth and death process.	8
	Renewal Theory: Elementary renewal theory, statement and uses of key renewal theorem.	4
	Branching process: Galton – Watson branching process, probability of ultimate extinction.	4
	Continuous process: Brownian motion.	2

References:

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.

2STAT2.3	**Large Sample Theory (Marks 40, Credit 2)**	**20**
	Convergence in distribution of random variables, Scheffe's theorem, Slutsky's theorem. Characteristic function of random vector and the Multivariate CLT (without proof)), δ-method of deriving the asymptotic distribution of a smooth function of an asymptotically normal sequence.	10
	Sample statistics: empirical distribution function, strong consistency, asymptotic distribution of the cdf.	4
	Quantiles: asymptotic normality.	3
	Order Statistics: Relation to quantiles, asymptotic distribution of extreme order statistics.	3

References:

1. P. Billingsley.
2. C.R. Rao: Linear Statistical Inference and its Applications, Wiley.
3. R.J. Serfling: Wiley.
4. S.S. Wilks: Wiley.
5. H. A. David.
6. E. L. Lehmann: Asymptotic Theory, Springer.

2STAT2.4	**Design of Experiments (Marks 80, Credit 3)**	**54**
	Block Designs – concepts of connectedness, orthogonality and balance: intrablock analysis.	8
	Variance Balance Design, BIB, Lattice and PBIB designs.	10
	Justification of missing plot techniques.	2
	Latin square and Youden square designs.	5
	Recovery of intrablock information, applications in BIBD.	5
	Construction of mutually orthogonal Latin Squares (prime power case), BIBD with resolvability.	7
	Factorial experiments, confounding and balance in symmetric factorials (prime power case), examples of (s^m, s^{m-1}) and (s^3, s^2), (s^4, s^3) designs without proof.	12
	Response surface experiments, first order designs and orthogonal designs	5

References:

1. Chakraborty, M.C.: Mathematics of Design and Analysis of Experiments.
2. Kempthorne, O.
3. Cochran, W.G. & Cox, G.M.
4. Federer.
5. Das & Giri.
6. Dey, Aloke (1986): Theory of Block designs (Wiley Eastern).
7. Joha, P.W.M. (1971).
8. Nigam, A.K. Puri, P.D. & Gupta, V.K.

9. Montgomey, D.C. (1976).
10. Myers, R.H. (1971) : Response Surface Mthodology (Allyn and Bacon).
11. Box & Draper.
12. Khuri & Cornell.

2STAT2.5	**Econometrics and Time Series Analysis (Marks 80, Credit 3)**	**45**
	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.	18
	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.	6
	Autocorrelated disturbance: Consequence on OLS estimation Tests for autocorrelation. Estimation and testing in CLRM with autocorrelated disturbance.	5
	Simultaneous equation models: identification and estimation.	4
	Review of classical decomposition method. Smoothing of time series using filters. Representation of time series as a stochastic process. Weakly and strongly stationary processes and their examples. Ergodicity. Autocorrelation and partial autocorrelation functions and their properties. AR, MA, ARMA models and their properties. Identification, estimation and diagnostic checking of ARMA models. Forecasting.	12

References:

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. Their, H. (1982): Introduction to the Theory and Practice of Econometrics

2STAT3.1	**Estimation Theory (Marks 70, Credit 3)**	**57**
	Sufficiency minimal Sufficiency, Factorization theorem in the dominated case (without proof), completeness, ancillarity, Basu's theorem. Unbiased estimation, Lehmann-Scheffe theorem, Chapman-Robbins inequality, Rao-Cramer Lower bound in the multiparameter case (statement only), Bhattacharyya inequality.	18
	Equivariant estimation with emphasis on location and scale, minimum risk equivariant estimators, Pitman estimator.	10
	Large sample considerations: consistency of estimators, consistency of the minimum likelihood estimator under Cramer type conditions, asymptotic normality of the one-step MLE, method of scoring (including the multiparameter set–up in all cases), asymptotic efficiency, Hodges' example, Bahadur's theorem on supper – efficient estimators (without proof).	16
	Confidence sets: relation with hypothesis testing; optimum confidence intervals.	6
	Resampling procedures in the context of estimation: the jackknife and bootstrap.	7

References:

1. Goon A.M., Gupta M.K., and Dasgupta, B.: An Outline of Statistical Theory, Vol 2, World Press.

2. Lehmann, E.L. and Casella, G.:Theory of Point Estimation, 2nd Ed, John Wiley.
3. Rao, C. R. (1973): Linear Statistical Inference & its Applications, Wiley.
4. Shao, J and Tu, D. (1995): The Jack Knife and Bootstrap, Springer.
5. Zacks, S. (1971): Theory of Statistical Inference, John Wiley.

2STAT3.2	**Testing of Hypothesis (Marks 70, Credit 3)**	**54**
	Neyman-Pearson lemma, monotone likelihood ratio property, one-sided hypothesis against a one sided alternative, generalized Neyman-Pearson lemma (without proof), two sided hypothesis in a one parameter exponential family, least favourable distributions.	28
	Locally best test (One sided), similar test, Neyman structure, UMPU test for a one-parameter exponential family.	8
	Likelihood Ratio test (LRT), Asymptotic distribution of LRT statistics under simple null hypothesis (real parameter only), Wald's test and Rao's score test, consistency of the LR test for simple hypothesis, Bartlett's test for homogeneity of variances.	8
	Sequential tests, SPRT and its properties, fundamental identity, OC and ASN, Wald's equation for ASN.	10

References:

1. Lehmann, E.L.: Testing Statistical Hypotheses.
2. Ferguson, T.S.: Mathematical Statistics-A Decision Theoretic Approach.
3. Rohatgi, V.: An Introduction to Probability and Mathematical Statistics.
4. Rao, C.R.: Linear Statistical Inference and its Applications.
5. Kendall, M.G. and Stuart, A.: The Advanced Theory of Statistics, Vol. II.
6. Goon, A.M., Gupta M.K. and Dasgupta, B.: An Outline of Statistical Theory, Vol II.

2STAT3.3	**Nonparametric Methods (Marks 70, Credit 3)**	**35**
	Runs test for randomness, Kolmogorov – Smirnov goodness of fit test, One sample location and scale problems, Wilcoxon signed rank	10

	statistic, median test, two sample homogeneity problem, Wolfowitz runs test and the two sample Kolmogorov-Smirnov test.	
	One and two-sample U-statistics, statement of the asymptotic normality of U-statistics, linear rank statistics, statement of the asymptotic normality under the hypothesis.	8
	Location and scale alternatives in the two sample problem, The median and the Mann-Whiteny tests, Mood's test and the normal and inverse normal scores tests.	6
	One –way and two – way classification, Kruskal – Wallis and Friedman's tests	3
	Measures of rank correlation: The Spearman's rho and Kendall's tau.	4
	Confidence intervals related to the Median and the Mann-Whitney tests in one and two sample problems.	4

References:

1. Gibbons.
2. Outline Vol2.
3. Randles & Wolfe.

2STAT3.4	**Decision Theory (Marks 70, Credit 3)**	**35**
	Elements of decision problem and associated concepts, statistical games and point estimation and testing of hypothesis as particular cases.	10
	Rao-Blackwell theorem (statement only).	1
	Statistical games with finite set of states of nature : The risk set, lower boundary set and the lower quantant, relation to admissible, minimax and Bayes rules.	10
	Statement of the separating hyperplane theorem, existence and admissibility of Bayes rules, completeness of the class of Bayes rules.	6
	Computation of minimax tests for one-sided hypothesis in MLR families.	8

References:

1. Ferguson, T. S.: Mathematical Statistics – A Decision Theoretic Approach, Academic Press.
2. Berger, J. O.: Statistical Decision Theory, Springer.

2STAT3.5	**SQC and Reliability (Marks 70, Credit 2)**	**37**
	SQC: General Theory and review of control charts for attributes and variable data: OC and ARL of control charts; moving average and exponentially weighted moving average charts; CUSUM charts using V-masks and decision intervals.	8
	Continuous sampling plans of Dodge type and Wald-Wolfowitz type and their properties.	4
	Capability indices CP, CPK and CPM.	3
	Acceptance sampling plan for attributes: Sequential sampling plan, Mil. Std. plan.	2
	Reliability: Reliability concepts and measures; components and systems, coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on systems reliability and reliability importance of components.	8
	Life distributions, reliability function; hazard rate; common life distributions - exponential, Weibull and gamma.	4
	Notions of ageing; IFR, IFRA, NBU, DMRL and NBUE and their duals; loss of memory property of the exponential distribution.	4
	Reliability estimation based on failure time in variability censored life-tests.	4

References:

1. D.C. Montgomery (1985): Introduction to Statistical Quality Control. Wiley.
2. Wetherill, G.B. (1977): Sampling Inspection and Quality control, Halsteed Press.
3. Wetherill, G.B. Brown, D.W.: Statistical Process Control Theory and Practice, Chapman & Hall.
4. Barlow, R.E. and Proschan, F (1985): Statistical Theory of Probability and Life Testing, Holt, Rinehart & Winston.
5. Lawless, J.F. (1982): Statistical Models and Methods of Life Data, John Wiley.

2STAT3.6	**R Programming (Marks 50, Credit 2)**	**49**
	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.	15
	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.	18
	Graphical procedures, high level and low level plotting commands, graphical parameters. Standard packages from R; some nonstandard statistical models, Dynamic graphs.	16

References:

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

SPECIAL PAPERS

2 (Two) papers to be offered from:

1. Advanced Data Analytic Techniques (ADDAT)
2. Advanced Multivariate Analysis (ADMA)
3. Applied Multivariate Analysis (APMA)
4. Advanced Design of Experiments (ADDE)
5. Advanced Sample Survey (ADSS)
6. Advanced Time Series Analysis (ADTSA)
7. Advanced Econometric Methods (ADEM)
8. Advanced Econometric Applications (ADEA)
9. Advanced Econometrics (ADE)
10. Statistical Genomics and Bioassay (SGB)
11. Survival Analysis (SA)
12. Advanced Inference (ADI)
13. Advanced Operations Research (ADOR)
14. Reliability and Survival Analysis (RSA)

Advanced Data Analytic Techniques (ADAT): Marks 100, Credit 4	**54**
Overdispersed Data	14
Missing Data	12
Data with measurement error.	16
Case Studies.	12

***References**:*

1. P.J. Diggle, K.Y.Liang & S.L. Zeger: Analysis of Longitudinal Data.
2. D. Hard & M. Crowder: Preacucal Longitudinal Data Analysis.
3. R. Carrol, D. Ruppert & L.A. Stefansky: Measurement Error in Nonlinear Models.
4. P.McCullagh & A.J. Nelder: Generalized Linear Models.

54

Advanced Multivariate Analysis (ADMA): Marks 100, Credit 4

Improved estimation of mean vector: James Stein estimator and its modifications.	6
Heuristic approach to test construction: union – intersection and step – down procedures and their applications to various problems involving normal distribution.	7
Invariant tests; Optimum properties of Hotelling's T^2 – test.	5
Test of covariance matrices: Sphericity test, test of independence, test of equality of several covariance matrices.	8
Testing equality of several normal populations.	4
Multivariate Behrens – Fisher problem.	3
Some admissibility results: Admissibility of Hotelling's T^2 – test and the LRT for testing independence.	4
General linear hypotheses and MANOVA.	10
Confidence regions and simultaneous confidence intervals involving mean vectors, dispersion matrices and regression matrices.	7

References:

1. Anderson, T.W. (1984): An introduction to Multivariate Statistical Analysis, 2nd Ed, John Wiley.
2. Giri, N.C. (1977): Aspects of Multivariate Statistical Theory, John Wiley.
3. Sirvastava, M.S. and Khatri, C.G. (1979): An Introduction to Multivariate Statistics, North Holland.
4. Muirhead, R. J.: Aspects of Multivariate Analysis, Wiley.

Applied Multivariate Analysis (APMA): Marks 100, Credit 4 **41**

Organization and representation of multivariate data.	6

Dimension Reduction Techniques :	
a) Principal Component Analysis Concept, Computation, Large sample Inferences.	5
b) Canonical Correlation Analysis: Concept, Computation, Large sample, Inferences.	5
c) Exploratory Factor Analysis: Concept, Factor model, estimation of factor landings, factor rotation, estimating factor scores, Model fit.	5
Multivariate Analysis of Variance: One-way and two-way classified data with one observation per cell.	5
Discriminate Analysis: Likelihood ratio, Bayes and minimax procedures, Discrimination between two multivariate normal populations with common dispersion, Sample discriminate function, estimation, Fisher's method for discriminating among several populations.	6
Cluster Analysis: Proximity measures, Hierarchical clustering techniques: single, complete and average linkage algorithms. Non-hierarchical clustering techniques: K-means method.	5
Multidimensional Scaling: Classical Metric Scaling, Non-metric scaling .	4

References:

1. Johnson, R.A. and Wichern, D.W.: Applied Multivariate Statistical Analysis.
2. Kshirsagan, A.M. Multivariate Analysis.
3. Morrison, D.F. Multivariate. Statistical Methods.
4. Seber, G.A.F. Multivariate Observations.
5. Mardia, Kent and Bibby.

Advanced Design of Experiments (ADDE): Marks 100, Credit 4	**60**
PBIB design: Classification of two associate association schemes,	15

uniqueness GD association schemes Construction of GD designs.	
Fractional factorial designs: ($1/2^k$ of 2^n experiments only) without blocking.	8
Response surface designs: Variance function, rotatable designs, analysis, some methods of construction of second order rotatable designs.	16
Optimum designs: different optimality criteria, optimality of standard designs, namely RBD, LSD, BIBD, YSD; optimality of BBD and GYD (regular setting).	12
	9

References:

1. Kempthorne, O.
2. Cochran & Cox.
3. Box & Hunter.
4. Raghava Rao (1971).
5. Shah & Sinha: Theory of Optimal Designs (Springer –Verlag).
6. Hedayat & Wallis (1978): Ann. Statist.

Advanced Sample Survey (ADSS): Marks 100, Credit 4	**53**
Unified theory of survey sampling, non existence theorems of Godambe (JRSSB, 1955) and Basu (in Godambe and Sprott's Foundations of Inference in survey Sampling, 1971**)** concerning uniformly minimum variance unbiased estimators; admissibility, sufficiency and minimal sufficiency, complete class theorem, unordering as a means to construct a complete class.	15
Issued in a small area estimation – Synthetic and generalized regression estimators, Kalman Filtering Technique.	10
Non-Sampling errors and biased responses, randomized responses for variables, errors in surveys, modeling observational errors, estimation of variance components, application of longitudinal studies (repetitive	10

surveys).

Variance estimation, method of random groups, balanced half samples (IPNSS), Jack-knife method.	8
Introduction to Superpopulation models, optimal design – unbiased strategies and optimal model-unbiased prediction under simple regression models.	10

References:

1. C.M. Cassel, C.E. Sarndal. & J.H. Wretman: Foundation of Inference in Survey Sampling.
2. A. Chaudhuri & J.W.E. Vos: Unified Theory and Strategies of Survey Sampling.
3. A.S. Hedayat & B.K. Sinha: Design and Inference in Finite Population Sampling.
4. P. Mukhopadhyay: Inferential Problem in Survey Sampling.
5. P. Mukhopadhyay: Small Area Estimation in Survey Sampling, Narosa.
6. C.E. Sarndal, B. Swensson & J. Wretman: Model Assisted Survey Sampling.

Advanced Time Series Analysis (ADTSA): Marks 100, Credit 4	**55**
Review of stationary processes – stationarity, autocovariance function, and its properties. Ergodicity. Sufficient conditions for ergodicity, ergodicity property of WN, AR, MA, ARMA processes. Autocovariance generating functions, ACGF for WN, AR, MA, ARMA processes. Review of identification, estimation and diagnostic checking of ARIMA processes. Specification and estimation of VARMA model. State – Space time series Models: State-Space representation of a dynamic system. Illustration using AR (p), MA(q), ARMA (p, q)	20
Forecasting: Minimum MSE forecast using ARIMA and VARMA models. Weiner-Kolmogorov (WK) prediction formula. Illustrations using ARMA model State –space Modeling. Kalman filter. Use of Kalman filter to calculate least squares forecast for the state vector and the vector of variables. Exact finite sample s-period ahead forecast with Kalman filter.	10

Non-stationary processes. Unit root tests and their large sample properties. Cointegration. Error correction model. Variance non-stationarity. Specification, properties, estimation and testing using ARCH and GARCH models.	10
The spectral representation of a stationary time series. Spectral density function and its properties. Spectral density of AR, MA, ARMA processes. Correspondence between time domain and frequency domain – Bochner's theorem, Weiner – Khinchine theorem. Estimation of spectral density function. Schuster's periodogram intensity function and its inconsistency. Nonparametric estimation of spectral density function.	15

***References**:*

1. Anderson, T.W. The Statistical Analysis of Time Series.
2. Greene, W.H. : Econometric Analysis
3. Hannan: Time series Analysis
4. Brockwell and Davis (2002): Introduction to Time Series and Forecasting, Springer.

Advanced Econometric Methods (ADEM): Marks 100, Credit 4	**54**
Estimation and Testing methods in Econometrics: Estimation: Maximum Likelihood, Quasi-Maximum Likelihood, Simulated Maximum Likelihood, GMM and EM estimation. Statement of the large sample properties of the estimators.	10
Tests based on ML principle: LR test, Rao's Score test, Wald's test. White's information matrix test, test for non-nested hypothesis.	5
Models with lagged variables: The lag and difference operators. Finite and infinite lag models. Autoregressive distributed lag models. Forecasting.	8
Discrete and limited dependent variable models : Specification,	15

estimation of (i)Binary choice models and its extension (ii) Multivariate probit model (iii) multivariate logit model (iv) count model (v) truncated and censored regression model (vi) Duration model.	
Panel Data Models: Specification, Estimation and Testing in the context of fixed, mixed and random effects models. GMM estimation of dynamic panel data models.	4
Specification testing and diagnostic checking. Inferential problems in mis-specified models.	4
Introduction to Nonparametric and semi-parametric regression.	8

References:

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

Advanced Econometric Applications (ADEA): Marks 100, Credit 4	**50**
Income and allied size distributions: Stochastic models of income distribution, Measurement of income inequality, problems of measurement, Indian studies on inequality and poverty.	10
Advanced demand analysis: Demand systems, zero expenditure and corner solutions, nonlinear budget frontiers, rationing, sources of dynamics in consumer behaviour, durable goods, non-parametric demand analysis.	10
Production analysis: Frontier production function, measurement of	10

productivity and technical change, flexible forms, aggregation, properties and estimation of multi-output production and cost functions.

Estimation of structural models of firm behaviour: Dynamic programming models, policy effects on productivity, capital formation and product – mix of firms, models of firm heterogeneity – measurement of product quality and efficiency differences among firms. 10

Empirical models of the labour market: Duration analysis, labour supply and labour demand functions including the impact of unionization, studies on the Indian labour market. 10

References:

1. Sen, A.: On Economic Inequality, Oxford.
2. Sen, A.: Poverty and Famine: An Essay on Entitlement and Deprivation, Oxford.
3. Deaton and Muellbauer. : Economic theory and Consumer Behaviour, Cambridge University Press.
4. Kumbhakar and Lovell: Stochastic Frontier Analysis, Oxford.

Advanced Econometrics (ADE): Marks 100, Credit 4 **55**

Capital Asset Price Model (CAPM). Estimation of CAPM by L.S., SURE and IV techniques; properties of the estimators. Statistical testing of the CAPM hypothesis. 5

Portfolio Analysis: Individual Portfolio and Market portfolio. Efficient portfolio rule. N-asset Mean-Variance (MV) portfolio model of Markkovich. Tangency portfolio. M-V frontier. Sharpe ratio. M-V portfolio choice with (i) predictable returns (ii) overlapping returns. Use of CAPM in portfolio analysis. 10

Modeling of asset returns: Test of White Noise (WN) hypothesis based on sample autocorrelations and variance rations. Specification, estimation and diagnostic checking of ARIMA model. Forecasting of 16

asset returns. Multivariate linear time series model : Specification and Estimation of VARMA. Analysis of Non-stationary financial data: unit root hypothesis, DF test. Co-integration. Error-correction model. Prediction of asset- return using variance – ratio, dividend – price ratio and lead – lag. Factor model of asset returns.

Modeling of asset price: Martingales and Random walk. Testing of Efficient market hypothesis. Statistical inference based on stochastic models of price dynamics. Modeling of option price in complete market. Black –Scholes formula (statement only) and its application. 12

Modeling and analysis of asset risk: Stochastic volatility model (SVM) Estimation of volatility in random walk. Risk modeling and estimation using of ARCH, GARCH and ARAM-GARCH models. Analysis of extreme risk. Estimation of Value-at-Risk (VaR). Confidence interval estimation of VaR using resampling technique. 12

References:

1) Camble, J.Y, A.W. Lo and A.C. MacKinlay (1997): The Econometrics of Financial Markets. Princeton University Press.
2) Gourieroux, C and J.Jasiak (2004): Financial Econometrics: Problems, Models and Methods.
3) Bodie, Z, A. Kane and A.J. Marcus (2002): Investments, McGraw-Hill, 5th edition.
4) Brockwell and Davis (2002): Introduction to Time Series and Forecasting, Springer.

Statistical Genomics and Bioassay (SGB): Marks 100, Credit 4 **52**

Statistical Genomics: 25

Introduction, Mendellian Genetics and Cytogenetics, Population Genetics, Quantitative Genetics, Molecular Genetics.Genetic Mapping, DNA sequencing, Single locus and two loci models. QTL mapping.

Bioassay: 27

Types of Biological Assays. Direct Assays, Ratio Estimators, asymptotic distributions. Fieller's Theorem .

Regression approaches to estimating dose – response relationships. Logit and probit approaches when dose – response curve for standard preparation is unkuown, Quantal responses, Method of estimation of parameters, estimation of extereme quantiles, does allocation schemes, polychotomous quantal response.

Estmation of points on the quantal response function.

References:

1. C.C.Li: First Course on Population Genetics.
2. W.J. Ewens: Mathematical Population Genetics.
3. P. Nagylaki: Introduction to Theoretical Population.
4. A. Krogh & G. Mitchison: Biological Sequence Analysis – Probabilistic Models of Proteins & Nucleic Acids.
5. Z. Govindarajulu: Statistical Techniques in Bioassay.
6. D.J. Finney: Statistical Methods in Bioassay.
7. D.J. Finney: Probit Analysis (3^{rd} edition).

Survival Analysis (SA): Marks 100, Credit 4	**55**
Introduction, Basic Quantities and Models.	8
Censoring and Truncation.	7
Topics in univariate estimation.	8
Nonparametric estimation.	7
Nonparametric estimation.	7
Semi-parametric properties	6
Regression Diagnostics.	6
Multivariate Survival Analysis.	6

References:

1. D.R. Cox & D. Oakes: Analysis of Survival Data.

2. A. J. Grouss & A.V. Clark: Survival Distribution – Reliability Applications in the Biomedical Sciences.
3. R.E.E. Johnson & N.L. Johnson: Survival Models and Data Analysis.
4. R.G. Miller: Survival Analysis.

Advanced Inference (ADI): Marks 100, Credit 4	**58**
Week compactness of critical functions (statement only) and its applications, generalized Neyman-Pearson Lemma, closure of the risk set from below in a two-action problem.	8
Maximin tests, most stringent tests, Hunt-Stein theorem.	10
EM algorithm.	6
Robustness concepts, Gateaux derivatives of von Mises functionals, influence curves – examples; robustness of M-estimators.	12
Multiple decision problems, problems on classification and ranking.	10
Invariant priors and invariant Bayes rules (statement only), non-informative and conjugate priors, posterior analysis.	12

References:

1. Lehmann, E. L.: Testing Statistical Hypotheses, 2nd ed.
2. Lehmann, E. L.: Theory of Point Estimation.
3. Lehmann, E. L. and Casella, G.: Theory of Point Estimation, 2nd ed.
4. Berger, J. O.: Statistical Decision Theory, Springer.
5. Serfling, E.: Approximation Theorems in Mathematical Statistics, Wiley.
6. Casella, G., and Berger, J. O.
7. McLachlan and Krishnan: The EM Algorithm.

Advanced Operations Research (ADOR): Marks 100, Credit 4	**56**
Sensitivity analysis in linear programming problems.	4
Nonlinear programming: graphical method, classical optimization technique, Kuhn-Tucker theorem, Wolfe's algorithm in quadratic	10

programming.

Dynamic programming, Bellman's principle of optimality, general formulation, applications.	6
Inventory problems, deterministic model, multiple item static model with storage limitation, continuous review model, ABC analysis.	8
Stochastic programming, chance-constrained programming under normality.	5
Integer programming, branch and bound and cutting plane method.	6
Simulation: Monte-Carlo method, generation of random observations from a few standard distributions.	6
Replacement problems, replacement of items that depreciate, block and age replacement policies, staffing problem.	6
Goal programming.	5

References:

1. Hadley.
2. Gass.
3. Taha.
4. Kambo.
5. Goel and Mittal.
6. Sharma.

Reliability and Survival Analysis (RSA): Marks 100, Credit 4	**60**
Life distributions, survival functions, hazard rate, hazard function, residual life time, mean residual life function, one-one correspondence of these functions, common life distributions, exponential, Weibull, gamma, Makeham, Pareto, Rayleigh and lognormal distribution.	5
Notions of ageing, IFR, IFRA, DMRL, NBU, NBUE, HNBUE classes and their duals for continuous and discrete setups. Exponential distribution and its non-ageing property, ageing properties of other	12

common life distributions, closure under formations of coherent structures, convolutions and mixtures.	
Univariate shock models and life distributions arising from shock models, vector concept of hazard rate, multivariate lack of memory property, properties of multivariate exponential distribution due to Marshall and Olkin.	9
Maintenance and replacement policies, relevant renewal theory, availability of repairable systems, optimization of system reliability with redundancy, spare parts allocation.	10
Parametric inference for various life distributions, moments and maximum likelihood estimation, likelihood ratio tests, tests based on the MLE, type I, II and random censoring schemes, estimation and testing based on these schemes for various parametric models.	12
Stress-strength model – determination and estimation; accelerated life testing.	12

References:

1. Barlow and Proschan.
2. Lawless, J. F. (1982): Statistical Models and Methods of Lifetime Data, Wiley.
3. Kapur and Lamberson.