Department of Statistics, University of Calicut
Master of Philosophy (M. Phil.) Degree Programme in Statistics
(Structure & Syllabi w.e.f. 2019 Admission onwards)

Duration: One year programme in two continuous semesters.
Total Credits: **24**

Semester-I (Total Credits: **12**) **June - November**

Paper-1: **Research Methodology** (**4** Credits)

Paper-2: **Advanced Trends in Statistics** (**4** Credits) and

Paper-3: **Specialization** (**Elective**) (**4** Credits)

- E01: Longitudinal Data Analysis
- E02: Stochastic Models in Queueing Theory
- E03: Advanced Queueing Systems
- E04: Laplace Distributions
- E05: Circular Distributions
- E06: Limit Theorems and Stability of Random Sums
- E07: Classical Extreme Value Models
- E08: Stochastic Models in Reliability
- E09: Modelling and Analysis of Inventory
- E10: Frailty Models in Survival Analysis
- E11: Discrete q- Distributions
- E12: Advances in Distribution Theory
- E13: Weibull and Related Distributions

Semester-II (Total Credits: **12**) **December - May**

Dissertation & Viva-voce (Core) (**10+2=12 Credits**)

Note: (1) Ratio of **Internal** & **External** Evaluation is **40: 60**
(2) Break-up of internal marks of 40:

Component	Weightage in %	Marks
Periodic Tests	50	20
Seminar	20	08
Classroom participation	10	04
Attendance	10	04
Assignments	10	04
	Total	**40**

MODEL QUESTION PAPER

First Semester M.Phil. Degree Examination in Statistics , Month–Year

Course no.:
Course Code /Title (_ Credits)

[Note: Answer any **Five** questions. Each question carries **12** marks.]

Time: **3** Hours | Maximum Marks: **60**

1. (a) …..
   (b) …...

2. (a) …..
   (b) …...

3. (a) …..
   (b) …...

4. (a) …..
   (b) …...

5. (a) …..
   (b) …...

6. (a) …..
   (b) …...

7. (a) …..
   (b) …...

8. (a) …..
   (b) …...

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Syllabus

Paper 1: Research Methodology in Statistics (4 Credits)

This course introduces some Statistical concepts and methods which potential students will find useful in preparing for work on a research degree in Statistics. Focus is on applications of state-of –the-art. Statistical techniques and their underlying theory.

Unit. I. Concept of Research in Statistics-Importance and Need for Research Ethics, Selection of Topic for Research-Research schedules, Review of Literature and its Use in Designing a Research Work-Mode of Literature Survey-Books and Monographs, Journals, Conference Proceedings, Abstracting and Indexing Journals, E-Journals/Books and CD-ROMS-Reports etc. Thesis Writing – Computer Application in Scientific Research-www-Searching Scientific Articles-Statistical Data Base. History of Statistics. Statistical Heritage of India.

Unit. II: Scientific Word Processing with LaTeX and MS-Word: Article, Thesis Report and Slides Making-Power Point Features, Slide Preparation. Statistical Programming with R: Simple Manipulations Using Numbers and Vectors-Objects & Their Attributes-Arrays and Matrices-Lists and Data Frames-Grouping, Loops and Conditions-User Defined Functions-Probability Distributions and Statistical Models in R.

Unit. III: Simulation: Concepts and Advantages of Simulation-Event Type Simulation-Random Variable Generation-U(0,1), Exponential, Gamma and Normal Random Variables – Monte Carlo Integration. The MCMC Principle, Algorithms and its Variants, Bootstrap Methods.

Unit. IV: Computer Oriented Numerical Methods-Algorithms for Solving Algebraic and Transcendental Equations-Numerical Integration-Matrix operations.

References

1. Anderson, J., Durston, B.H., Pooole, M. (1970) Thesis and Assignment Writing. Wiley Eastern. Ltd., New Delhi.

2. Beveridege, B. (1979) The Art of Scientific Investigation. W.E. Norton & Co., New York.
3. Braun, J., Duncan, W. and Murdock, J. (2008) A First Course in Statistical Programming with R. Cambridge University Press, London.
4. Chambers, J. (2008) Software for Data Analysis: Programming with R. Springer, New York.
5. Crewley, M.J. (2007) The R-.Book. John Wiley, New York.
6. Dalgaard, P.(2008) Introductory Statistics with R. Springer Science, New York.
7. Ghosh, J.K., Mitra, S.K. and Parthasarathy, K. R.(1992) Glilmpses of India's Statistical Heritage. Wiley Eastern Limited, New Delhi.
8. Hald, A.(1998) A History of Mathematical Statistics from 1750 to 1930. John Wiley & Sons, New York.
9. Kantiswarup, S., Gupta P.K. and Man Mohan (2008) Operations Research. Sultan Chand & Sons, New Delhi.
10. Kothari, C. (2005) Research Methodology. New Age International. Publishers,
New York.
11. Lamport, L. (1999) LATEX: A Document Preparation System. Addison, Wesley, 2nd edition, New York
12. Pannerselvan,R. (2006) Research Methodology. Prentice-Hall of India. Pvt., NewDelhi.
13. Robert, C.P. and Casella, G. (2004) Monte Carlo Statistical Methods. Springer Science, New York.
14. Venkataraman, M.K. (1998) Numerical Methods in Science and Engineering. The National Publishing Company, Chennai.

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Paper 2: Advanced trends in Statistics (4 Credits)

Unit I. Distribution Theory: Systems of Distributions –Johnson's S_B System, Johnson's S_u System, Burr Distributions. Infinite Divisibility of Probability Distributions: Infinitely Divisible Distribution on (i) The Non-Negative Integers.(ii) The Non-Negative Reals.

Unit II: U-Statistics: Basic Description of U-Statistics- The Variance and Other Moments of a U- Statistic- The Projection of a U-Statistic on the Basic Observations- Almost Sure Behavior of U-Statistics- Asymptotic Distribution Theory of U-Statistics, Non-parametric density estimation.

Unit III: Generalized Linear Models: (GLM). The Origin of GLM-An Outline of GLM-Models with Continuous Data with Constant Variance-Binary Data- Polytomous Data-Log- Linear Models-Models for Survival Data.

Unit IV: Stochastic Order Relations: Stochastically Larger, Couplings, Hazard Rate Ordering, Likelihood Ratio Ordering, Variability Ordering-Applications-Associated random variables.

References

1. Laha, R.G. and Rotatgi, V.K. (1979). Probability Theory. Wiley, New York.
2. Mc Cullagh, P. and Nelder, J.A (1983). Generalized Linear Models. Chapman and Hall Ltd., Cambridge.
3. Ross, S.M.(1996). Stochastic Processes (Chapter-9). John Wiley & Sons, New York.
4. Serfling, R.J.(1980). Approximation Theorems of Mathematical Statistics (Chapter-5). John Wiley and Sons, Canada.
5. Steutel, F.W. and van Harn, K. (2004). Infinite Divisibility of Probability Distributions on the Real Line. Marcel Dekker Inc., New York.

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Paper 3: Specialization (Elective)

E01: Longitudinal Data Analysis (4 Credits)

Unit-I: General Linear Model for Longitudinal Data.ML and REML Estimation, EM Algorithm: General Linear Mixed-Effects Model, Inference for; the Random Effects, BLUPs, Empirical Bayes, Bayes, Shrinkage Model Building and Diagnostic, Relaxing Parametric Assumptions: Generalized Additive Mixed Model.

Unit-II: Generalized Linear Model for Longitudinal Data: Marginal Models, for Binary, Ordinal, and Count Data: Random Effects Models for Binary Ordinal and Count Data: Transition Models: Likelihood-Based Models for Categorical Data; GEE; Models for Mixed Discrete and Continuous Responses.

Unit-III: Dropouts and Missing Data: Classification of Missing Data Mechanisms; Intermittent Missing Values and Dropouts; Weighted Estimating Equations; Modeling the Dropout Process (Selection and Pattern Mixture Models).

Unit-IV: Time-Dependent Covariates and Special Topics: Dangers of Time-Dependent Covariates: Lagged Covariates; Marginal Structural Models; Joint Models for Longitudinal and Survival Data; Multivariate Longitudinal Data; Design of Randomized and Observational Longitudinal Studies.

References

1. Diggle, P.J., Heagerty, P., Liang, K.Y and Zeger. S.L (2003) Analysis of Longitudinal Data, 2nd Edn. Oxford University press, New York.
2. Fitzmaurice, G.M., Laird, N.M. and Ware, J.H.(2004) Applied Longitudinal Analysis. John Wiley & Sons, New York.
3. Crowder, M.J. and Hand, D.J. (1990) Analysis of Repeated Measures. Chapman and Hall/CRC Press, London .
4. Davidian, M. and Giltinan, D.M. (1995) Nonlinear Models for Repeated Measurement Data. Chapman and Hall/CRC Press, London.
5. Hand,D and Crowder, M. (1996) Practical Longitudinal Data Analysis. Chapman and Hall/CRC Press, New York.
6. Lindsey, J.K. (1993) Models for Repeated Measurements. Oxford University Press, New York.
7. Little, R.J.A. and Rubin, O.B. (2002) Statistical Analysis with Missing Data, 2nd edition, Wiley, New York.
8. McCullagh, P. and Nelder, J.A (1989) Generalized Linear Models. 2nd edition, Chapman and Hall/CRC Press, London.
9. Weiss, R.E. (2005) Modeling Longitudinal Data. Springer, New York.

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Paper 3: Specialization (Elective)

E02: Stochastic Models in Queuing Theory (4 Credits)

Unit I: Markovian Queuing Models: M/M/1 Queues, M/M/1/K Model., M/M/∞ Model, M/M/c Model, Transient Behavior of M/M/1 Systems, $M/E^k/1$ and $E^k/M/1$ Systems., Bulk Queues $M^x/M/1$, $M/M^{(a,b)}/1$ Models.

Unit II: Network. of Queues: Markovian Queues; Tandem queues, Jackson Network, Gordon and Newell Network, Cyclic Queue, BCMP Networks.

Unit III: Non-Markovian Queueing Systems: Embedded. Markov Chain Technique for M/G/1 model, Pollaezck-Khinchin Formula, Busy Period. Narration of M/G/1/N, M^X/G/1; $M/G^{(a,b)}/1$ Model, G/M/1 Model, Transient State Distribution of M/G/∞ Model; Markov Renewal Process and Semi-Markov Processes.

Unit IV: Vacation Models and Retrial Queues: Queuing Systems with Vacations-Stochastic Decompositions. M/G/1 Systems with Vacations. Retrial Queuing Systems - Model Description -M/M/1, M/G/1 Retrial Queues-Heavy Tailed Distributions-M/G/1 System with Heavy Tailed Service Time.

References

1. Medhi, J. (2003) Stochastic Models in Queuing theory. Second Edition, Academic Press, Elsevier Science(USA).
2. Bhat, B.R. (2000) Stochastic Models-Analysis and Application. New Age International Publishers, New Delhi.
3. Gross, D. and Harris, C.M. (1985) Fundamentals of Queuing Theory, 2^{nd} Edn. John Wiley & Sons, New York.
4. Bose, S.K.(2002). An Introduction to Queuing systems. Kluwer Academic/ Plenum Publishers, New York.
5. Cinlar, E.(1975). Introduction to Stochastic Processes, Prentice-Hall, Englewood Cliffs, New Jersey.

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Paper 3: Specialization (Elective)

E03: Advanced Queueing Systems (4 Credits)

Unit I: Basic Queueing Theory: Model Parameters-Basic Models. Kendall's Notation-Little's Result-Equilibrium Solutions for M/M/-/- Queues-Delay Analysis for M/M/1/∞/FCFS Model-Departure Process from M/M//∞ Queues -Time Reversibility Property of MCs-Queues with Bulk/Batch Arrivals.

Unit II: Performance Analysis of M/G/1 Queue in Equilibrium: The Residual Life Approach-The Imbedded MC Approach-Distributions of Time Spent in System and Waiting Time Prior to Service-Busy Period Analysis- Delay Analysis.

Unit III: Advanced Queueing Theory: M/G/1 Queue with Vacation-$M^{(x)}$/G/1 Queue-Single Server M/G/1 Priority Queues. The Discrete Time Geo/G/1 and Geo $^{(x)}$/G/1 Queues.

Unit IV: Queuing Networks and Advances: Classification of Queuing Networks-Probabilistic Routing-Open and Closed Networks. Convolution and MVA Algorithms- Norton's Theorem for Closed Queueing Networks-Mixed Queueing Networks-Approximation Techniques-Models of Blocking. Simulation Techniques for Queues and Queueing Networks: Discrete Event Simulation-Simulator Outputs for Queues-Estimation of Confidence Intervals and Levels-Transient Behavior and Warm-up Interval-Data Collection in Steady State Conditions.

References

1. Bose, S.K. (2002) An Introduction to Queuing Systems. Kluwar Academic Plenum Publishers, New York.
2. Kleinrock,L (1975) Queuing System.Vol.I, John Wiley & Sons, New York.
3. Gross, D. and Harris, C.M. (1985) Fundamentals of Queuing Theory, 2nd edn. John Wiley & Sons, New York.
4. Medhi, J. (2003) Stochastic Models in Queueing Theory. Second edition, Academic Press, Elsevier Science ,USA.

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Paper 3: Specialization (Elective)

E04: Laplace Distributions (4 Credits)

Unit I: Historical Background, Definition and Basic Properties- Density and Distribution Functions, Characteristic Function, Moments and Related Parameters, Entropy, Quartiles and Quantiles.

Unit II: Representations and Characterizations- Mixture of Normal, Relation to Exponential, Pareto, Stability with respect to Geometric Summation, Distributional Limits of Geometric Sums, Stability with respect to the Ordinary Summation.

Unit III: Order Statistics- Distribution of a Single Order Statistics- the Minimum, Maximum, Median, Joint Distribution of Order Statistics-Range, Mid Range, Sample Median, Point Estimation- MLE, MLE Under Censoring, MLE of Monotone Location Parameters, The Method of Moments, Linear Estimation.

Unit IV: Testing of Hypothesis- Testing Normal versus Laplace, Goodness of Fit Tests, Neyman-Pearson Test for Location, Asymptotic Optimality of KS Test, Comparison of Non-Parametric Tests for Location.

References

1. Kotz, S., Kozubowski, T.J. and Podgorski, K. (2001) The Laplace Distribution and Generalizations. Birkhauser, Boston.
2. Johnson, N. L., Kotz,S. and Balakrishnan, N. (1994) Continuous Univariate Distributions - Vol. I &II (Second Edition), Wiley, New York.
3. Lehmann, E.L. (1983) Theory of Point Estimation. Wiley, New York.
4. Rohatgi, V.K.(1984) Statistical Inference. Wiley, New York.

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Paper 3: Specialization (Elective)

E05: Circular Distributions (4 Credits)

Unit I: Descriptive Measures of Circular Distributions- Mean Direction, Median Direction, Mode, Circular Variance, Circular Mean Deviation, Quartile Deviation, Circular Range, Trigonometric Moments, Skewness and Kurtosis.

Unit II: Distribution Function, Characteristic Function, Fourier Steiltjes Series, Independence, Theorems on Characteristic Functions, Circular Models- Point Distribution, Uniform Distribution, Cardioid Distribution.

Unit III: Von Mises Distribution, Shape, Relation with Other Distributions, Characteristic Function and Moments, Distribution Function, Characterizations.

Unit IV: Wrapped Distributions- Definition and Properties, Wrapped Poisson, Wrapped Normal, Wrapped Cauchy, Generalized Wrapped Stable Distributions.

References

1. Jammalamadaka S. Rao and Sen Gupta, A. (2001) Topics in Circular Statistics. World Scientific, New York.
2. Mardia, K.V. (1972) Statistics of Directional Data. Academic Press, London.
3. Mardia, K. V. and Jupp, P.E. (2000) Directional Statistics. Wiley, New York.

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Paper 3: Specialization (Elective)

E06: Limit Theorems and Stability of Random Sums (4 Credits)

Unit I: Stable Probabilistic Schemes: Summation Stable Distributions- Strictly and Symmetric Stable Vectors, Domains of Attraction, One Dimensional Case; Max-Stable and Min-Stable Distributions, Multiplication Stable Distributions, Geometric Summation Stable Distributions, Geometric Max-Stable, Geometric Min-Stable, Geometric Multiplication Stable Distributions

Unit II: Central Pre-limit Theorems- Introduction and Motivating Examples, Central Pre-limit theorems, ν- Infinitely Divisible Distributions and Stable Distributions: Sums of a Random Number of Random Variables- Examples, Limit Theorems and Transfer Theorems, ν- Gaussian Random Variables, Examples of Summation Schemes Admitting Schemes ν- Strictly Gaussian Laws, ν- Infinitely Divisible Random Variables. Accompanying Laws.

Unit-III: Approximation of Random Sums- Approximation of Geometric Sums, Random Sums of Random Vectors, Domains of Attraction of Multivariate Geometrically Stable Laws, Bounds for Random Sums, Domain of Attraction of ν-Stable Random Vectors, Rate of Convergence.

Unit IV: Geometric Stable Distributions on the Real Line- Preliminaries; Special Cases- Strictly GS Laws, Linnik Distributions, Symmetric Linnik Distributions, Mittag-Leffler Distributions; Stability Properties and Characterizations- Representations- Basic Representation, Alternative Representation- Linnik Distributions, Mittag-Leffler Laws, Strictly GS Laws, General Case; Densities and Distribution Functions- General GS Laws.

References

1. Kalashnikov, V. (1997) Geometric Sums: Bounds for Rare Events with Applications, Kluwer Acad.Publ., Dordrecht.
2. Klebanov, L.B., Kozubowski, T.J. and Rachev, S.T. (2006) Ill-Posed Problems in Probability and Stability of Random Sums. Nova Science Publishers, Inc., New York.
3. Gnedenko, V. and Korolev, Yu.V. (1996). Random Summation: Limit Theorems and Applications. CRC Press, Boca Raton.

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Paper 3: Specialization (Elective)

E07: Classical Extreme Value Models (4 Credits)

Unit I: Maximum, minimum and other order statistics of a sequence ofiid random variables - stability of maxima and minima, Inverse functions and Khintchine's theorem, Max-stable distributions, Extremal types theorem, Type I, Type II and Type III extreme value distributions, Generalised Extreme Value Distributions (GEVD), Convergence of $P(M_n \leq u_n)$.

Unit II: Domain of attraction problem - domain of attraction criteria forType I, Type II and Type III extreme value distributions, Sufficient condition for the domain of attraction - examples.

Unit III: Point process approach to extremes - basic facts about point processes - definition and examples, Point process of exceedance in the iid case. Generalised Pareto Distribution (GPD), Derivation of the asymptotic distri-bution of maxima and other order statistics using point process approach.

Unit IV: Statistical method for extremal events, Exploratory data analysis forextremes - probability and quantile plots - mean excess function - Gumbel's method of exceedances. Parametric estimation for GEVD - Maximum likeli-hood estimation, method of probability weighted moments, Fitting excesses over a threshold - fitting the GPD.

References

1. Embrechts, P., Kluppelberg, C. and Mikosch, T. (1997) Modelling Ex-tremal Events for Insurance and Finance. Springer, Berlin.
2. Leadbetter, M.R., Lindgren, G., and Rootzen, H. (1983) Extremes and Related Properties of Random Sequences and Processes. Springer-Verlag, New York.
3. Resnick, S.I. (1987) Extreme Values, Regular Variation and Point Pro-cesses, Springer, New York.

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Paper 3: Specialization (Elective)

E08: Stochastic Models in Reliability (4 Credits)

Unit-I. Reliability concepts and measures; components and systems; coherent systems; reliability of coherent systems; cuts and paths; modular decomposition; bounds on system reliability; structural and reliability importance of components.

Unit-II. Life distributions; reliability function; hazard rate; common life distributions-exponential, Weibull, Gamma etc. Estimation of parameters and tests in these models. Notions of ageing; IFR, IFRA, NBU, DMRL, and NBUE Classes and their duals; closures or these classes under formation of coherent systems, convolutions and mixtures.

Unit-III. Univariate shock models and life distributions arising out of them; bivariate shock models; common bivariate exponential distributions and their properties. Reliability estimation based on failure times in variously censored life tests and in tests with replacement of failed items; stress-strength reliability and its estimation.

Unit-IV. Maintenance and replacement policies; availability of repairable systems; modeling of a repairable system by a non-homogeneous Poisson process. Reliability growth models; probability plotting techniques; Hollander-Proschan and Deshpande tests for exponentiality; tests for HPP vs. NHPP with repairable systems. Basic ideas of accelerated life testing.

Text Books / References

1. **Barlow R.E. and Proschan F**.(1985). Statistical Theory of Reliability and Life Testing; Holt,Rinehart and Winston.
2. **Bain L.J. and Engelhardt** (1991). Statistical Analysis of Reliability and Life Testing Models; Marcel Dekker.
3. **Aven, T**. and **Jensen,U.** (1999). Stochastic Models in Reliability, Springer-Verlag, New York, Inc.
4. **Lawless, J.F.** (2003). Statistical Models and Methods for Lifetime (Second Edition), John Wiley & Sons Inc., New Jersey.
5. **Nelson, W** (1982) Applied Life Data analysis; John Wiley.
6. **Zacks, S.** (1992). Introduction to Reliability Analysis: Probability Models and Statistics Methods. New York: Springer-Verlag,

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Paper-3: Specialization (Elective)

E09: Modelling and Analysis of Inventory (4 Credits)

Unit I: Classical Models:
Basic knowledge and vocabulary of inventory management, Inventory theory for single-commodity single-installation Systems: Deterministic inventory models, stochastic inventory models. Newsvendor (NV) Models: Single period, stochastic demand; Base-stock policies: Multiple periods, stochastic demand; (s, S) policies: Multiple periods, stochastic demand, fixed costs.

Unit II: Inventory theory for Multi-commodity Multi-installation Systems:
Deterministic models-The two-commodity problem; multi-commodity problem; single period probabilistic models- the two-commodity problem; the multi-commodity problem.

Unit III: Single-Echelon Models & Stochastic Leadtimes:
Fundamentals; types of inventory models; EOQ with imperfect quality and present-value criterion; DEL model and extensions; world-driven demand; Approximations, optimization, extensions. Independent leadtimes, capacity constraints; Exogenous supply systems, leadtime distribution.

Unit IV: Multi-Echelon Models, Policy Optimization, Dynamic Programming and Supply chain processes:
Independent and serial systems; Tree systems, the JRP, the ELSP; the Clark-Scarf model. Assembly and distribution systems. Linear order costs; Fixed-plus-linear order costs. Dynamic programming and Inventory models; Multi-stage Inventory Models; basic ideas of Supply Chain Management.

References

1. Sivazlian, B. D. and Stanfel, L. E. (1975). *Analysis of Systems in Operations Research*, Prentice-Hall, INC, Englewood Cliffs, New Jersey (Chapter 5 & 6).
2. Zipkin, Paul H. (2000). *Foundation of Inventory Management*, Boston: McGraw–Hill.
3. Porteus, Evan L. (2002). *Foundations of Stochastic Inventory Theory*, Stanford, CA: Stanford University Press.
4. Axsater, Sven (2000). *Inventory Control*, Norwell, MA: Kluwer.
5. Silver, Edward A., David F. Pike, and Rein Peterson (1998). *Inventory Management and Production Planning and Scheduling,* 3rd Edition, Hoboken, NJ: Wiley.

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Paper-3: Specialization (Elective)

E10: Frailty Models in Survival Analysis (4 Credits)

UNIT I: Survival Analysis – Basic concepts, Censoring and Truncation, Estimation of Survival and Hazard Functions, PH model, AFT model, Identifiability problems, Concept of Univariate Frailty, Discrete Frailty Model, Gamma Frailty Model, Log normal Frailty Model, Inverse Gaussian, Positive stable, PVF, Compound Poisson, Quadratic Hazard , Levy's, Log – t Frailty Models, Univariate Frailty Cure Models, Missing Covariates in PH Models.

UNIT II: Shared Frailty Models – Marginal versus Frailty Model, Concept of Shared Frailty, Shared Gamma Frailty Model, Shared Log normal, Shared Positive Stable, Shared Compound Poisson/PVF Frailty Models, Shared Frailty Models More General, Dependence Measures, Limitations of Shared Frailty Models.

UNIT III: Correlated Frailty Models – Concept of Correlated Frailty, Correlated Gamma Frailty Model, Correlated Log- normal Frailty Model, MCMC methods for the Correlated Log- normal Frailty Model, Correlated Compound Poisson Frailty Model, Correlated Quadratic Compound Poisson Frailty Model, Correlated Quadratic Hazard Frailty Model, Other Correlated Models, Bivariate Frailty Cure Models, Comparison of Different Estimation Strategies, Dependent Competing Risks in Frailty Models.

UNIT IV: Copula Models and Different Aspects of Frailty Modelling – Shared Gamma Frailty Copula, Correlated Gamma Frailty Copulas, General Correlated Frailty Copula, Cross – Ratio Function, Dependence & Interaction between Frailty and Observed Covariates, Cox Model with General Gaussian Random effects, Nested Frailty Models, Log - Rank in Frailty Models, Identifiability of Frailty Models, Applications of Frailty Models.

Reference Texts/ Text Books:

1. Duchateau, L. and Janssen, P (2008). The Frailty Model. Springer, New York.
2. Nelson, R.B (2006). An Introduction to Copulas. Springer, New York.
3. Wienke, A (2011) Frailty Models in Survival Analysis. Chapman & Hell / CRC Press, New York.

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Paper-3: Specialization (Elective)

E11: Discrete q- Distributions (4 Credits)

UNIT I: q – Factorials and q – Binomial Coefficients, q – Vandermonde's and q – Cauchy's Formulae, q – Binomial and Negative q -Binomial Formulae, General q – Binomial Formula and q – Exponential Functions, q – Stirling Numbers, Generalized q – Factorial Coefficients, q – Factorial and q- Binomial Moments.

UNIT II: q – Binomial Distribution of the First Kind, Negative q – Binomial distribution of the First Kind, Heine distribution, Heine Stochastic Process, q – Stirling Distribution of the First Kind.

UNIT III: Negative q – Binomial Distribution of Second Kind, q – Binomial Distribution of the Second Kind, Euler Distribution, Euler Stochastic Process, q – Logarithmic Distribution, q – Stirling Distribution of the Second Kind.

UNIT IV: q – Polya Distribution, q – Hypergeometric Distributions, Inverse q – Polya Distribution, Inverse q – Hypergeometric Distributions, Generalized q – Factorial Coefficient Distributions.

Text Books/ Reference Texts:

1. Charalambides, C. A. (2016) Discrete q- Distributions, Wiley, New York.
2. Johnson, N.L., Kemp, A.W and Kotz, S. (2005) Univariate Discrete Distributions, 3_{rd} Edn., Wiley, New York.
3. Zelterman, D. (2004) Discrete Distributions, Wiley, New York

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Paper-3: Specialization (Elective)

E12: Advances in Distribution Theory (4 Credits)

UNIT I: Preliminaries: Probabilistic descriptions: Unimodality, Hazard functions and Hazard rates, reverse Hazard functions and reverse hazard rates, MRLF, Odds ratio, Families of Distributions, Mixtures of Distributions, Parametric families: basic examples, Non – parametric families: basic examples, Functions of random variables, Inverse Distributions: The Lorentz curve and the Total Time on Test Transform.

UNIT II: Non- Parametric Families: Densities and Hazard rates. Introduction, log – concave and log – convex densities, monotone hazard rates, bath tub hazard rates, Determination of hazard rate shape.

UNIT III: Semi- Parametric Families: Introduction, location parameters, scale parameters, power parameters, Frailty and Resilience parameters: Proportional Hazard and Reverse Hazard. Tilt parameters: Proportional odds ratio, Extreme stable families; Hazard power parameters, Moment parameters, Laplace transform parameters, Convolution parameters, Age parameters, Successive Additions of parameters, Mixing semi parametric families, Additional semi parametric families, Distributions not admitting parameters.

UNIT IV: Parametric Families: Parametric Extension of the exponential distribution- Exponential distribution with a Resilience parameter, with a Tilt parameter, Residual life distribution, connection with logistic distribution, ordering distribution with Tilt parameter, limits , Comparison with the Weibull and gamma families, An alternative derivation, Gamma - Weibull Distribution, Weibull distribution with a Resilience parameter, Residual life of Weibull distribution, Weibull distribution with a Tilt parameter, Generalized gamma convolutions. Pareto distribution: Basic definitions, The hierarchy of Pareto and related distributions, The Pareto IV distribution, Gini index and coefficient of variation, Residual life distribution, Pareto IV distribution from mixtures, Infinite divisibility, Pareto distribution as limiting distribution, limits of Pareto distribution, Transformation and Pareto distribution, Pareto distribution with a Tilt parameter,. Logistic and Cauchy distributions – genesis, characterizations and applications.

References:

1. Balakrishnan, N. (1992). Hand book of the logistic distributions. Marcel Dekker Inc., New York.
2. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2004). Continuous Univariate Distributions – Volume I (Second Edition). Wiley Student Edition. John Wiley and Sons (Asia) Pte. Ltd., Singapore.
3. Johnson, N.L., Kotz, S. and Balakrishnan, N. (2004). Continuous Univariate Distributions – Volume II (Second Edition). Wiley Student Edition. John Wiley and Sons (Asia) Pte. Ltd., Singapore.
4. Marshall, A.W. and Olkin, I. (2007). Life Distributions: Structure of Non parametric, Semi parametric and Parametric Families. Springer, New York

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Paper-3: Specialization (Elective)

E13: Weibull and Related Distributions (4 Credits)

UNIT I: Definition and properties of Weibull distribution – functions describing life time as a random variable, failure density – three parameter density, two parameter and one parameter densities, analysis of reduced Weibull density, failure distribution and reliability function, hazard rate, mean residual life function, aging criteria, percentiles and random number generation, moments, cumulants and their generating functions.

UNIT II: Related distributions – systems of distributions and Weibull distribution – Pearson system -BURR system – Johnson system – Weibull and other families of distributions – Weibull and exponential – Weibull and extreme value – Weibull and gamma – Weibull and normal distributions.

UNIT III: Modifications of the Weibull distribution – discrete Weibull distribution, reflected and double Weibull distributions, inverse Weibull distributions, log Weibull distribution, truncated Weibull distributions, four and five parameter Weibull distributions, Weibull distribution with time dependent parameter, bivariate and multivariate Weibull distributions, characterizations of Weibull distributions – based on functional equations, conditional moments, order statistics.

UNIT IV: Parameter estimation – graphical approaches – probability plots, hazard plots, TTT plots, Weibull plotting techniques, maximum likelihood approaches, method of moments, more classical approaches and comparisons.

Text Books/ Reference Texts:

1. Murthy, D.N.P., Xie, Min and Jiang, R (2004). Weibull Models, John Wiley and sons. New York.
2. Rinne, H (2009). The Weibull Distribution – A Hand Book. CRC Press. New York

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Sd/-
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