Course Curricula : M.Sc. (Applied Statistics and Informatics)

FIRST YEAR

Semester I

Course No.	Name	L	T	P	C
CS101	Computer Programming & Utilization	2	0	2	6
SI 423	Linear Algebra and Applications	3	1	0	8
SI 417	Introduction to Probability Theory	3	1	0	8
SI 419	Combinatorics	2	1	0	6
SI 425	Basic Real Analysis	3	1	0	8
	Total Credits	**13**	**4**	**2**	**36**

Semester II

Course No.	Name	L	T	P	C
SI 402	Statistical Inference	3	1	0	8
SI 404	Applied Stochastic Processes	2	1	0	6
SI 416	Optimization	2	1	0	6
SI 418	Advanced Programming & Unix Environment	0	0	3	3
SI 422	Regression Analysis	3	0	2	8
SI 408	Data Structures	3	1	0	8
	Total Credits	**13**	**4**	**5**	**39**

SECOND YEAR

Semester III

Course No.	Name	L	T	P	C
ES 200	Environmental Studies	3	0	0	3
HS 200	Environmental Stduies	3	0	0	3
SI 505	Multivariate Analysis	3	1	0	8
SI 503	Categorical Data Analysis	3	1	0	8
	Elective I	3	1	0	8
	Elective II	2	1	0	6
SI 593	Project I (Optional)	-	-	-	4
	Total Credits	**15**	**4**	**0**	**36**

Semester IV

Course No.	Name	L	T	P	C
SI 509	Time Series Analysis	3	1	0	8
SI 526	Experimental Designs	2	1	0	6
	Elective III	2	1	0	6
	Elective IV	2	1	0	6
	Elective V	2	1	0	6
SI 598	Project II/Dept. Elective/Institute Elective	-	-	-	6
	Total Credits	**11**	**5**	**0**	**38**

Electives – Semester III

Elective I	
MA 419	Basic Algebra
SI 529	Applied Algorithms
MA 417	Ordinary Differential Equations
SI 507	Numerical Analysis
MA 533	Advanced Probability
Elective II	
SI 525	Testing of Hypothesis
SI 528	Biostatistics
SI 511	Computer Aided Geometric Design
SI 515	Statistical Techniques in Data Mining

Electives – Semester IV

Elective III	
SI 512	Finite Difference Methods for Partial differential Equations
SI 534	Nonparametric Statistics
SI 513	Theory of Sampling
SI 532	Statistical Decision Theory
Elective IV and V	
SI 514	Statistical Modeling
SI 527	Introduction to Derivative Pricing
SI 530	Statistical Quality Control
SI 542	Mathematical Theory of Reliability
SI 536	Analysis of Multi-type & Big Data 3 0 0 6

COURSE CONTENTS

CS 101 Computer Programming And Utilization 2 0 2 6

This course provides an introduction to problem solving with computers using a modern language such as Java or C/C++. Topics covered will include : Utilization : Developer fundamentals such as editor, integrated programming environment, Unix shell, modules, libraries. Programming features : Machine representation, primitive types, arrays and records, objects, expressions, control statements, iteration, procedures, functions, and basic i/o. Applications : Sample problems in engineering, science, text processing, and numerical methods.

Cohoon and Davidson, C++ Program Design: An introduction to Programming and Object-Oriented Design, 3rd Edition, Tata McGraw Hill, 2003.

Texts / References

Bruce Eckel, Thinking in C++ 2nd Edition.

G. Dromey, How to Solve It by Computer, Prentice-Hall, Inc., Upper Saddle River, NJ, 1982.

Polya, G., How to Solve _It (2nd ed.), Doubleday and Co., 1957.

Yashwant Kanetkar , Let Us C, Allied Publishers, 1998.

The Java Tutorial, Sun Microsystems. Addison-Wesley, 1999.

ES 200 Environmental Studies 3 0 0 3

Multidisciplinary nature of environmental problems; Ecosystems, Biodiversity and its conservation; Indicators of environmental pollution; Environment and human health; Utilization of natural resources and environmental degradation. Sustainable development; Environmental policy and law; Environmental impact assessment; Pollution of lakes, rivers and groundwater. Principles of water and wastewater treatment; Solid and hazardous waste management. Air Pollution: sources and effects, Atmospheric transport of pollutants; Noise pollution; Global issues and climate change: Global warming, Acid rain, Ozone layer depletion.

Texts / References

Cunningham W.P. and Cunningham M.A., Principles of Environmental Science, Tata McGraw-Hill Publishing Company, New Delhi, 2002.

Nathanson, J.A., Basic Environmental Technology: Water Supply Waste Management and Pollution Control, 4th Ed. Prentice Hall of India, New Delhi, 2002.

Masters, G.M., Introduction to Environmental Engineering and Science, Prentice-Hall of India, Second Indian Reprint, 2004.

Davis, M. L. and Cornwell D. A., Introduction to Environmental Engineering, 2nd Ed.**,** McGraw Hill, Singapore, 1998.

Wright, R.T., Environmental Science: Towards a Sustainable Future, 9th Ed, Prentice Hall of India, New Delhi, 2007.

Supplementary Reading Materials (Selected Book Chapters and Papers)

HS 200 Environmental Studies 3 0 0 3

Social Issues and the environment, Public awareness and Human rights, Indicators of sustainability, Governance of Natural Resources - Common pool resources: issues and management.

Environmental ethics, Religion and environment, Wilderness and Developing Trends, Environmental movements and Activism, Social Ecology and Bioregionalism, Environmental justice.

Environmental economics, Trade and environment, Economics of environmental regulation, Natural resource accounting, Green GDP.

Environment and development, Resettlement and rehabilitation of people, Impacts of climate change on economy and society, Vulnerability and adaptation to climate change.

Texts / References

Agar, N., Life's Intrinsic Value, New York: Columbia University Press, 2001.

Dasgupta, P. and Maler, G. (eds.), The Environment and Emerging Development Issues, Vol. I, OUP. 1997.

Guha, Ramachandra, "Mahatama Gandhi and Environmental Movement," Debating on Gandhi, in A. Raghuramaraju (ed.), New Delhi: Oxford University Press, 2006.

Guha, Ramachandra and Madhav Gadgil, Ecology and Equity: The Use and Abuse of Nature in Contemporary India, New Delhi: Penguin, 1995.

Hanley, Nick, Jason F. Shogren and Ben White, Environmental Economics in Theory and Practice, New Delhi: MacMillan, 2004.

Naess, A. and G. Sessions, "Basic Principles of Deep Ecology," Ecophilosophy, Vol.6, 1984.

Redclift, M. and Woodgate, G. (eds.), International Handbook of Environmental Sociology, Edward Edgar, 1997.

MA 417 Ordinary Differential Equations 3 1 0 8

Review of solution methods for first order as well as second order equations, Power Series methods with properties of Bessel functions and Legendre polynomials.

Existence and Uniqueness of Initial Value Problems: Picard's and Peano's Theorems, Gronwall's inequality, continuation of solutions and maximal interval of existence, continuous dependence.

Higher Order Linear Equations and linear Systems: fundamental solutions, Wronskian, variation of constants, matrix exponential solution, behaviour of solutions.

Two Dimensional Autonomous Systems and Phase Space Analysis: critical points, proper and improper nodes, spiral points, and saddle points.

Asymptotic Behavior: stability (linearized stability and Lyapunov methods).

Boundary Value Problems for Second Order Equations: Green's function, Sturm comparision theorems and oscillations, eigenvalue problems.

Texts / References

R. P. Agarwal and R. Gupta, Essentials of Ordinary Differential Equations, Tata McGraw-Hill Publ. Co., New Delhi, 1991.

M. Braun, Differential Equations and their Applications, 4th Edition, Springer Verlag, Berlin, 1993.

E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw-Hill Publ. Co., New Delhi, 1990.

L. Perko, Differential Equations and Dynamical Systems, 2nd Edition, Texts in Applied Mathematics, Vol. 7, Springer Verlag, New York, 1998.

M. Rama Mohana Rao, Ordinary Differential Equations: Theory and Applications. Affiliated East-West Press Pvt. Ltd., New Delhi, 1980.

D. A. Sanchez, Ordinary Differential Equations and Stability Theory: An Introduction, Dover Publ. Inc., New York, 1968.

MA 419 Basic Algebra 3 1 0 8

Review of basics: Equivalence relations and partitions, Division algorithm for integers, primes, unique factorization, congruences, Chinese Remainder Theorem, Euler ϕ-function.

Permutations, sign of a permutation, inversons, cycles and transpositions. Rudiments of rings and fields, elementary properties, polynomials in one and several variables, divisibility, irreducible polynomials, Division algorithm, Remainder

Theorem, Factor Theorem, Rational Zeros Theorem, Relation between the roots and coefficients, Newton's Theorem on symmetric functions, Newton's identities, Fundamental Theorem of Algebra, (statement only), Special cases: equations of degree 4, cyclic equations.

Cyclotomic polynomials, Rational functions, partial fraction decomposition, unique factorization of polynomials in several variables, Resultants and discriminants.

Groups, subgroups and factor groups, Lagrange's Theorem, homomorphisms, normal subgroups. Quotients of groups, Basic examples of groups (including symmetric groups, matrix groups, group of rigid motions of the plane and finite groups of motions).

Cyclic groups, generators and relations, Cayley's Theorem, group actions, Sylow Theorems.

Direct products, Structure Theorem for finite abelian groups.

Texts / References

M. Artin, Algebra, Prentice Hall of India, 1994.

D.S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.

J.A. Gallian, Contemporary Abstract Algebra, 4th ed., Narosa, 1999.

K.D. Joshi, Foundations of Discrete Mathematics, Wiley Eastern, 1989.

T.T. Moh, Algebra, World Scientific, 1992.

S. Lang, Undergraduate Algebra, 2nd Ed., Springer, 2001.

S. Lang, Algebra, 3rd ed., Springer (India), 2004.

J. Stillwell, Elements of Algebra, Springer, 1994.

MA 533 Advanced Probability 3 1 0 8

Probability measure, probability space, construction of Lebesgue measure, extension theorems, limit of events, Borel-Cantelli lemma.

Random variables, Random vectors, distributions, multidimensional distributions, independence.

Expectation, change of variable theorem, convergence theorems.

Sequence of random variables, modes of convergence. Moment generating function and characteristics functions, inversion and uniqueness theorems, continuity theorems, Weak and strong laws of large number, central limit theorem.

Radon Nikodym theorem, definition and properties of conditional expectation, conditional distributions and expectations.

Texts / References

P. Billingsley, Probability and Measure, 3rd ed., John Wiley & Sons, New York, 1995.

J. Rosenthal, A First Look at Rigorous Probability, World Scientific, Singapore, 2000.

A.N. Shiryayev, Probability, 2nd ed., Springer, New York, 1995.

K.L. Chung, A Course in Probability Theory, Academic Press, New York, 1974

SI 402 Statistical Inference 3 1 0 8

Prerequisites : MA 411
MA 438 (Exposure)

Uniformly most powerful unbiased tests, Invariance in Estimation and Testing, Admissibility, Minimax and Bayes Estimation, Asymptotic Theory of Estimation, Asymptotic distribution of likelihood ratio statistics.

Sequential Estimation, Sequential Probability, Ratio Test.

Texts / References

G. Casella and R.L. Berger, Statistical Inference, Wadsworth and Brooks, 1990.

E.L. Lehmann, Theory of Point Estimation, John Wiley, 1983.

E.L. Lehmann, Testing Statistical Hypotheses, 2nd ed., Wiley, 1986.

R.J. Serfling, Approximation Theorems of Mathematical Statistics, Wiley, 1980

SI 404 Applied Stochastic Process 2 1 0 6

Stochastic processes : description and definition. Markov chains with finite and countably infinite state spaces. Classification of states, irreducibility, ergodicity. Basic limit theorems. Statistical Inference. Applications to queuing models.

Markov processes with discrete and continuous state spaces. Poisson process, pure birth process, birth and death process. Brownian motion.

Applications to queuing models and reliability theory.

Basic theory and applications of renewal processes, stationary processes. Branching processes. Markov Renewal and semi-Markov processes, regenerative processes.

Texts / References

U. N. Bhat, Elements of Applied Stochastic Processes, Wiley, 1972.

V.G. Kulkarni, Modeling and Analysis of Stochastic Systems, Chapman and Hall, London, 1995.

J. Medhi, Stochastic Models in Queuing Theory, Academic Press, 1991.

R. Nelson, Probability, Stochastic Processes, and Queuing Theory: The Mathematics of Computer Performance Modelling, Springer-Verlag, New York, 1995

SI 408 Data Structures 3 1 0 8

Tools for Analysis of Algorithms (Asymptotics, Recurrence Relations). Algorithms on arrays and matrices. Data Structures (Linked Lists and their variants, Stacks, Queues, Trees, Heaps and some variants) and applications. Sorting, Searching and Selection (Binary Search, Insertion Sort, Merge Sort, Quick Sort, Radix Sort, Counting Sort, Heap Sort etc.. Median finding using Quick-Select, Median of Medians). Basic Graph Algorithms (BFS, DFS, strong components etc.). Dijkstra's Shortest Paths algorithm, Bellman Ford algorithm, All pairs shortest path problem - Floyd Warshall's algorithm.

Texts / References

R. Sedgewick, Algorithms in C, Addison-Wesley, 1992.

T. Cormen, C. Leiserson, R. Rivest and C. Stein, Introduction to Algorithms, MIT Press, 2001.

M.A. Weiss, Data Structures and Algorithms Analysis in C++, Addison-Wesley, 1999.

Jon Kleinberg and Eva Tardos – Algorithm Design, Addison-Wesley, 2005

SI 416 Optimization 2 1 0 6

Unconstrained optimization using calculus (Taylor's theorem, convex functions, coercive functions).

Unconstrained optimization via iterative methods (Newton's method, Gradient/ conjugate gradient based methods, Quasi-Newton methods).

Constrained optimization (Penalty methods, Lagrange multipliers, Kuhn-Tucker conditions).

Introduction to Linear Programming.

Texts / References:

Bazaraa M.S., Sherali H.D., and Shetty C.M., Nonlinear Programming: Theory and Algorithms, 3rd Edition, Wiley, 2006.

Beale E.M.L and Mackley L., Introduction to Optimization, John Wiley, 1988.

Chavatal V., Linear Programming. W.H. Reeman and Company, 1983.

Chong E.P.K. and Zak S.H., An Introduction to Optimization, 2nd Edition, Wiley-Interscience Series in Discrete Mathematics and Optimization, NY: Wiley, 2004.

Joshi M.C. and Moudgalya K., Optimization: Theory and Practice, Narosa, New Delhi, 2004.

Nocedal Jorge and Wright Stephen J., *Numerical Optimization*, 2nd Edition, Springer, New York, 2006.

Ruszczy´nski Andrzej, *Nonlinear Optimization*, Princeton University Press, New Jersey, 2006.

Vanderbei R.J., Linear Programming Foundations and Extensions, 3rd Edition, Springer, 2008.

SI 417 Introduction to Probability Theory 3 1 0 8

Axioms of Probability, Conditional Probability and Independence, Random variables and distribution functions, Random vectors and joint distributions, Functions of random vectors.

Expectation, moment generating functions and characteristic functions, Conditional expectation and distribution. Modes of convergence, Weak and strong laws of large numbers, Central limit theorem.

Texts / References

P. Billingsley, Probability and Measure, II Edition, John Wiley & Sons (SEA) Pvt. Ltd., 1995.

P.G. Hoel, S.C. Port and C.J. Stone, Introduction to Probability, Universal Book Stall, New Delhi, 1998.

J.S. Rosenthal, A First Look at Rigorous Probability Theory, World Scientific. 2000.

M. Woodroofe, Probability with Applications, McGraw-Hill Kogakusha Ltd., Tokyo, 1975.

SI 418 Advanced Programming and Unix Environment 0 0 3 3

UNIX programming environment (file system and directory structure, and processes). Unix tools (shell scripting, grep, tar, compress, sed, find, sort etc). Graphical User Interface Programming using Java. Multithreaded programming in Java. Socket programming in Java.

Texts / References

Eckel, Thinking In Java, http://www.bruceeckel.com/javabook.html

B. Forouzan and R. Gilberg, Unix and Shell Programming: A Textbook, 3rd ed., Brooks/Cole, 2003.

B.W. Kernighan and R. Pike, Unix Programming Environment, Prentice Hall, 1984.

SI 419 Combinatorics 2 1 0 6

Prerequisites : MA 401, MA 402

Basic Combinatorial Objects: Sets, multisets, partitions of sets, partitions of numbers, finite vector spaces, permutations, graphs etc.

Basic Counting Coefficients: The twelve fold way, binomial, q-binomial and the Stirling coefficients, permutation statistics, etc.

Sieve Methods: Principle of inclusion-exclusion, permutations with restricted positions, Sign-reversing involutions, determinants etc.

Introduction to combinatorial reciprocity. Introduction to symmetric functions.

Texts / References

C. Berge, Principles of Combinatorics, Academic Press, 1972.

K.D. Joshi, Foundations of Discrete Mathematics, Wiley Eastern, 2000.

R.P. Stanley, Enumerative Combinatorics, Vol. I, Wadsworth and Brooks/Cole, 1986.

SI 422 Regression Analysis 3 0 2 8

Prerequisites: SI 417 Introduction to Probability Theory

Simple and multiple linear regression models – estimation, tests and confidence regions. Check for normality assumption. Likelihood ratio test, confidence intervals and hypotheses tests; tests for distributional assumptions. Collinearity, outliers; analysis of residuals, Selecting the Best regression equation, transformation of response variables. Ridge's regression.

Texts / References

B.L. Bowerman and R.T. O'Connell, Linear Statistical Models: An Applied Approach, PWS-KENT Pub., Boston, 1990

N.R Draper. And H. Smith., Applied Regression Analysis, John Wiley and Sons (Asia) Pvt. Ltd., Series in Probability and Statistics, 2003.

D.C. Montgomery, E.A. Peck, G.G. Vining, Introduction to Linear Regression Analysis, John Wiley, NY, 2003

A.A. Sen and M. Srivastava, Regression Analysis – Theory, Methods & Applications, Springer-Verlag, Berlin, 1990.

SI 423 Linear Algebra and Applications 3 1 0 8

Linear independence of vectors in Euclidean space. Subspace and dimension. Inner product and Gram-Schmidt orthonormalization.

Matrices: Null space. Row space and column space. Rank-Nullity theorem.

Systems of linear equations: Elementary row operations. LU decomposition.
Gaussian elimination. Rank and determinant. Cramer’s Rule.

Eigenvalues and eigenvectors: Algebraic and geometric multiplicity of an eigenvalue. Bounds on eigenvalues. Rayleigh quotients. Power method and QR method for finding approximate eigenvalues.

Special matrices: orthogonal, unitary, hermitian, symmetric, skew-symmetric, Hadamard, Projection matrices.

Diagonalization and the spectral theorem for symmetric matrices.

Least squares problem.

Finite dimensional vector spaces over fields (with emphasis on R and C). Bases, Linear Transformations, and their matrix representation.

Linear, bilinear and quadratic forms.

Inverses, generalized inverse and Moore Penrose inverse.

Partitioned matrices and applications. Kronecker products.

Books/References:

Linear Algebra and Linear Models (3/E) by R.B. Bapat, Trim Series, 2012.

Matrix Algebra: Theory, Computations and Applications in Statistics by J.E. Gentle, Springer, 2007

Matrix Algebra Useful for Statistics, S. R. Searle, John Wiley, Hoboken, 2006

Linear algebra and its applications (4th Edition) by G. Strang, Thomson, 2006

Fundamentals of Matrix Computations by D.S. Watkins, 2nd ed., Wiley, New York, 2002.

SI 425 Basic Real Analysis 3 1 0 8

Review of sequences and series of real numbers. Tests for convergence of Series. Limit superior and limit inferior. Cauchy sequences and completeness of R.

Basic notions of Metric Spaces with emphasis on R^n. Connectedness, Compactness, and Heine Borel Theorem.

Continuity and Uniform continuity. Monotone functions and functions of bounded variation.

Derivatives. Mean Value Theorem and applications.

Riemann Stieltjes integral. Riemann's Criterion for integrability. Improper integrals and the Gamma function.

Sequences and series of functions. Uniform convergence (proofs should be omitted).

Functions of several variables: Directional derivative, partial derivative, total derivative, Mean Value Theorem, Taylor's Theorem and applications to Maxima/Minima and convexity. Double and triple integrals. Statement of Fubini's Theorem and change of variable formula (without proofs) with illustrations.

Texts/References:

T. M. Apostol, Mathematical Analysis, 2nd ed., Narosa Publishers, New Delhi, 2002.

R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 4th ed., John Wiley, New York, 2011.

S. R. Ghorpade and B. V. Limaye, A Course in Calculus and Real Analysis, Springer (India), New Delhi, 2006.

R. R. Goldberg, Methods of Real Analysis, 4th Edition, Oxford and IBH Publishing Co., New Delhi.

K. A. Ross, Elementary Analysis: The Theory of Calculus, 2nd ed., Springer (India), New Delhi, 2013.

SI 503 Categorical Data Analysis 3 1 0 8

Two-way contingency tables: Table structure for two dimensions. Ways of comparing proportions. Measures of associations. Sampling distributions. Goodness-of-fit tests, testing of independence. Exact and large sample inference.

Models of binary response variables. Logistic regression. Logistic models for categorical data. Probit and extreme value models. Log-linear models for two and three dimensions. Fitting of logit and log-linear models. Log-linear and logit models for ordinary variables.

Regression: Simple, multiple, non-linear regression, likelihood ratio test, confidence intervals and hypotheses tests, tests for distributional assumptions Collinearity, outliers, analysis of residuals. Model building, Principal component and ridge regression. Lab component: Relevant real life problems to be done using statistical Software Packages such as SAS etc.

Texts / References

A. Agresti, Analysis of Categorical Data, Wiley, 1990.

A. Agresti, An Introduction to Categorical Data Analysis, Wiley, New York, 1996.

E.B. Andersen, The Statistical Analysis of Categorical Data, Springer-Verlag, 1990.

R.F. Gunst and R.L. Mason, Regression Analysis and its Applications – A Data Oriented Approach, Marcel Dekkar, 1980.

T.J. Santner and D. Duffy, The Statistical Analysis of Discrete Data, Springer-Verlag, 1989.

A.A. Sen and M. Srivastava, Regression Analysis – Theory, Methods and Applications, Springer-Verlag, 1990

SI 505 Multivariate Analysis 3 1 0 8

Prerequisites : SI 402 statistical Inference

K-variate normal distribution. Estimation of the mean vector and dispersion matrix. Random sampling from multivariate normal distribution. Multivariate distribution theory. Discriminant and canonical analysis. Factor analysis. Principal components.

Distribution theory associated with the analysis.

Texts / References

T.W. Anderson, An Introduction to Multivariate Statistical Analysis, 2nd Ed., Wiley, 1984.

R. Gnanadesikan, Methods for Statistical Data Analysis of Multivariate Observations, John Wiley, New York, 1997.

R.A. Johnson and D.W. Wicheran, Applied Multivariate Statistical Analysis, Upper Saddle River, Prentice Hall, 1998.

M.S. Srivastava and E.M. Carter, An Introduction to Multivariate Statistics, North Holland, 1983.

SI 507 Numerical Analysis 3 1 0 8

Principles of floating point computations and rounding errors.

Systems of Linear Equations: factorization methods, pivoting and scaling, residual error correction method.

Iterative methods: Jacobi, Gauss-Seidel methods with convergence analysis, conjugate gradient methods.

Eigenvalue problems: only implementation issues.

Nonlinear systems: Newton and Newton like methods and unconstrained optimization.

Interpolation: review of Lagrange interpolation techniques, piecewise linear and cubic splines, error estimates.

Approximation : uniform approximation by polynomials, data fitting and least squares approximation.

Numerical Integration: integration by interpolation, adaptive quadratures and Gauss methods

Initial Value Problems for Ordinary Differential Equations: Runge-Kutta methods, multi-step methods, predictor and corrector scheme, stability and convergence analysis.

Two Point Boundary Value Problems : finite difference methods with convergence results. Lab. Component: Implementation of algorithms and exposure to public domain packages like LINPACK and ODEPACK.

Texts / References

K.E. Atkinson, An Introduction to Numerical Analysis, Wiley, 1989.

S.D. Conte and C. De Boor, Elementary Numerical Analysis – An Algorithmic Approach, McGraw-Hill, 1981.

K. Eriksson, D. Estep, P. Hansbo and C. Johnson, Computational Differential Equations, Cambridge Univ. Press, Cambridge, 1996.

G.H. Golub and J.M. Ortega, Scientific Computing and Differential Equations: An Introduction to Numerical Methods, Academic Press, 1992.

J. Stoer and R. Bulirsch, Introduction to Numerical Analysis, 2nd ed., Texts in Applied Mathematics, Vol. 12, Springer Verlag, New York, 1993.

SI 509 Time Series Analysis 3 1 0 8

Prerequisites: SI 402 Statistical Inference

Stationary processes – strong and weak, linear processes, estimation of mean and covariance functions. Wald decomposition Theorem.

Modeling using ARMA processes, estimation of parameters testing model adequacy, Order estimation.

Prediction in stationery processes, with special reference to ARMA processes. Frequency domain analysis – spectral density and its estimation, transfer functions.

ARMAX, ARIMAX models and introduction to ARCH models.

Multivariate Time Series, State Space Models.

Texts / References

P. Brockwell and R. Davis, Introduction to Time Series and Forecasting, Springer, Berlin, 2000.

G.E.P. Box, G. Jenkins and G. Reinsel, Time Series Analysis-Forecasting and Control, 3rd ed., Pearson Education, 1994.

C. Chatfield, The Analysis of Time Series – An Introduction, Chapman and Hall / CRC, 4th ed., 2004.

SI 511 Computer-Aided Geometric Design 2 1 0 6

Polynomial curves: Bezier representation, Bernstein polynomials, Blossoming, de Castlijau algorithm. Derivatives in terms of Bezier polygon. Degree elevation. Subdivision. Nonparametric Bezier curves.

Composite Bezier curves. Spline curves: Definition and Basic properties of spline functions, B-spline curves, de Boor algorithm. Derivatives. Insertion of new knots. Cubic spline interpolation. Interpretation of parametric continuity in terms of Bezier polygon. Geometric continuity. Frenet frame continuity. Cubic Beta splines and significance of the associated parameters. Tensor product surfaces. Bezier patches. Tri-angular patch surfaces.

Texts / References

G. Frain, Curves and Surfaces for Computer Aided Geometric Design : A Practical Guide, Academic Press, 1988.

L. Ramshaw, Blossoming : A Connect-the-Dots Approach to Splines, DEC systems Research Center, Report no. 19, 1987.

SI 512 Finite Difference Methods for Partial Differential Equations 2 1 0 6

Pre-requisite:

Description: Review of 2nd order PDEs : Classification, separation of variables and fourier transform techniques. Automatic mesh generation techniques : Structure mesh (transfinite interpolation), unstructured grids (triangulation for polygonal and non - polygonal domains).Finite difference Methods : Elliptic equations (SOR and conjugate gradient methods, ADI schemes), parabolic equations (explicit, back - ward Euler and Crank - Nicolson method, LOD), hyperbolic equations (Law - Wendroff scheme, Leapfrod method, CFL conditions), Stability, consistency and convergence results. Lab Component : Implementation of Algorithms developed in this course and exposure to software packages : ODEPACK and MATLAB.

Texts / References

Gene H. Golub and James M. Ortega, Scientific Computing and Differential Equations : An Introduction to Numerical Methods, Academic Press, 1992.

P. Knupp and S. Steinberg, Fundamentals of Grid Generation, CRC Press Inc., Boca Raton, 1994.

A. R. Mitchell and D. F. Griffiths, The finite Difference Methods in Partial Differential Equations, Wiley, 1980.

G. D. Smith, Numerical Solutions of Partial Differential Equations, Oxford Press, 1985.
J. C. Stickwards, Finite Difference Schemes and PDEs, Chapman and Hall, 1989.

J. F. Thompson, Z. U., A. Waarsi and C. W. MAstin, Numerical Grid Generations - Foundations and Applications, North Holland, 1985.

Erich Zauderer, Partial Differential Equations of Applied Mathematics, 2nd ed., Wiley, 1989.

SI 513 Theory of Sampling 2 1 0 6

Simple random sampling. Sampling for proportions and percentages.

Estimation of sample size. Stratified random sampling, Ratio estimators. Regression estimators. Systematic sampling. Type of sampling unit, Subsampling with units of equal and unequal size. Double sampling. Sources of errors in surveys.

A brief introduction to randomized response techniques and small area estimation

Texts / References

Chaudhuri and H. Stenger, Survey Sampling: Theory and Methods, Marcell Dekker, 1992.

W.G. Cochran, Sampling Techniques, 3rd ed., Wiley Eastern, 1977.

P. Mukhopadhyay, Theory and Methods of Survey Sampling, Prentice-Hall of India, New Delhi, 1998.

Des Raj, Sampling Theory, Tata McGraw-Hill, 1978.

SI 514 Statistical Modeling 2 1 0 6

Prerequisites: SI 402 Statistical Inference

Nonlinear regression, Nonparametric regression, generalized additive models,

Bootstrap methods, kernel methods, neural network, Artificial Intelligence, a few topics from machine learning.

Texts / References

T. Hastie, and R. Tibshirani, Generalized Additive Models, Chapman and Hall, London, 1990.

G.A.F. Seber, and C.J. Wild, Nonlinear Regression, John Wiley & Sons, 1989.

W. Hardle, Applied Nonparametric Regression, Cambridge University Press, London, 1990.

SI 515 Statistical Techniques in Data Mining 2 1 0 6

Pre-requisite: SI 402 Statistical Inference.

Introduction to Data Mining and its Virtuous Cycle.

Cluster Analysis: Hierarchical and Non-hierarchical techniques. Classification and Discriminant Analysis Tools: CART, Random forests, Fisher's discriminant functions and other related rules, Bayesian classification and learning rules.

Dimension Reduction and Visualization Techniques: Multidimensional scaling, Principal Component Analysis, Chernoff faces, Sun-ray charts.

Algorithms for data-mining using multiple nonlinear and nonparametric regression.

Neural Networks: Multi-layer perceptron, predictive ANN model building using back-propagation algorithm. Exploratory data analysis using Neural Networks – self organizing maps. Genetic Algorithms, Neuro-genetic model building.

Discussion of Case Studies.

Texts / References

L. Breiman, J.H. Friedman, R.A. Olschen and C.J. Stone, Classification of Regression Trees, Wadsowrth Publisher, Belmont, CA, 1984.

D.J. Hand, H. Mannila and P. Smith, Principles of Data Minng, MIT Press, Cambridge, MA 2001.

M.H. Hassoun, Fundamentals of Artificial Neural Networks, Prentice-Hall of India, New Delhi 1998.

T. Hastie, R. Tibshirani & J. H. Friedman, The elements of Statistical Learning: Data Mining, Inference & Prediction, Springer Series in Statistics, Springer-Verlag, New York 2001.

R.A. Johnson and D.W. Wichern, Applied Multivariate Analysis, Upper Saddle River, Prentice-Hall, N.J. 1998.

S. James Press, Subjective and Objective Bayesian Statistics: Principles, Models, and Applications, 2nd Edition, Wiley, 2002.

SI 525 Testing of Hypothesis 2 1 0 6

Prerequisites: SI 402 Statistical Inference

Statistical hypotheses, Neyman-Pearsaon fundmeantal lemma, Monotone likelihood

ratio, confidence bounds, generalization of fundamental lemma, two-sided hypotheses.

Unbiased tests, UMP unbiased tests, applications to standard distributions, similarity and completion, Pemutation tests; most powerful permutation tests.

Symmetry and invariance, most powerful invariant tests, unbiased and invariance.

Tests with guaranteed power, maxi-min tests and invariance. Likelihood ratio tests and its properties.

Texts / References

E.L. Lehmann, Testing Statistical Hypotheses, 2nd ed. Wiley, 1986.

T.S. Ferguson, Mathematical Statistics: A Decision Theoretic Approach, Academic Press, New York, 1967.

G. Casella and R.L. Berger, Statistical Infwerence, Wordsworth & Brooks, California, 1990.

SI 526 Experimental Designs 2 1 0 6

Prerequisites: SI 402 Statistical Inference

Linear Models and Estimators, Estimability of linear parametric functions. Gauss-Markoff Theorem. One-way classification and two-way classification models and their analyses. Standard designs such as CRD, RBD, LSD, BIBD. Analysis using the missing plot technique.
Fctorial designs. Confounding. Analysis using Yates' algorithm. Fractional factorial.

A brief introduction to Random Effects models and their analyses.

A brief introduction to special designs such as split-plot, strip-plot, cross-over designs.

Response surface methodology.

Applications using SAS software.

Texts / References

A.M. Kshirsagar, A First Course in Linear Models, Marcel Dekker, 1983.

D.C. Montgomery, Design and Analysis of Experiments, 3rd Ed., John Wiley & Sons, 1991.

C.F.J. Wu and M. Hamada, Experiments: Planning Analysis, and Parameter Design Optimization, John Wiley & Sons, 2002.

SI 527 Introduction to Derivative Pricing 2 1 0 6

Introduction to options and markets: types of options, interest rates and present value.

Black-Scholes Model: arbitrage, option values, payoffs and strategies, put call parity, Black-Scholes equation, similarity solution and exact formulae for European options. American options: call and put options, free boundary problem.

Binomial methods: option valuation, dividend paying stock, general formulation and implementation. Monte-Carlo simulation: valuation by simulation.

Finite Difference Methods: explicit and implicit methods with stability and convergence analysis, methods for American option-constrained matrix problem, projected SOR, time stepping algorithms with convergence and numerical examples.

Lab Component: Implementation of the option pricing algorithms and Evaluation for Indian companies.

Texts / References

L. Clewlow and C. Strickland, Implementing Derivative Models, Wiley Series on Financial Engineering, John Wiley and Sons, Chichester, 1998.

J. C. Hull, Options, Futures and Other Derivatives, 4th ed., Prentice Hall of India, New Delhi, 2000.

P. Wilmott, S. Howison and J. Dewynne, The Mathematics of Financial Derivatives: A Student Introduction, Cambridge University Press, Cambridge, 1995.

P. Wilmott, J. Dewynne, and S. Howison, Option Pricing: Mathematical Models and Computation, Oxford Financial Press,

Oxford, 1993.

SI 528 Biostatistics 2 1 0 6

Pre-requisite: SI 402 Statistical Inference

Introduction to clinical trials and other types of clinical research, bias and random error in clinical studies, overview of Phase I-IV trials, multi-center trials; randomized, controlled clinical trials; concept of blinding/masking in clinical trials.

Design of Phase 1-3 clinical trials: parallel vs. cross-over designs, cross-sectional vs. longitudinal designs, review of factorial designs, objectives and endpoints of clinical trials, formulation of appropriate hypotheses (equivalence, non-inferiority, etc.); sample size calculation; design for bioequivalence/ bioavailability trials, sequential stopping in clinical trials.

Analysis of Phase 1-3 trials: Use of generalized linear models; analysis of categorical outcomes, Bayesian and non-parametric methods; analysis of survival data from clinical trials

Epidemiological studies: case-control and cohort designs; odds ratio and relative risk; logistic and multiple regression models.

Texts / References

S.C. Chow and J.P. Liu, Design and Analysis of Clinical Trials - Concepts & Methodologies, John Wiley & Sons, NY, 1998.

S.C. Chow and J.P. Liu, Design and Analysis of Bioavailability & Bioequivalence Studies, Marcel Dekker, 2000.

W.W. Daniel, Biostatistics: A Foundation for Analysis in the Health Sciences (6th ed.), John Wiley, NewYork, 2002.

J.L. Fleiss, The Design and Analysis of Clinical Experiments, John Wiley & Sons, 1986.

D.W. Hosmer and S. Lemeshow, Applied Logistic Regression, John Wiley and Sons, NY, 1989.

E. Vittinghoff, D.V. Glidden, S.C. Shiboski and C.E. McCulloch, Regression Methods in Biostatistics, Springer Verlag, 2005.

J.G. Ibrahim, M-H Chen and D. Sinha, Bayesian survival analysis, Springer, NY, 2001.

SI 529 Applied Algorithms 3 1 0 8

Algorithm Design Paradigms:

Divide and Conquer,

Greedy Algorithms (for example, some greedy scheduling algorithms, Kruskal's Minimum Spanning Tree Algorithm).

Dynamic Programming (for example, dynamic programming algorithms for optimal polygon triangulation, optimal binary search tree, longest common subsequence, matrix chain multiplication, all pairs shortest paths).

Selection of some of the following topics:

- Randomized algorithms-Monte Carlo and Las Vegas algorithms, Role of Markov and Chebyscheff's inequalities, Chernoff bounds in randomized algorithms, applications of probabilistic method,
- Approximation Algorithms for NP Hard problems,
- Semi definite programming based algorithms
- Exact Exponential time algorithms for NP-hard problems (such as better than brute-force algorithms for Chromatic number, Independent Set, Satisfiability, etc.)

Texts / References

J. Kleinberg and E. Tardos, Algorithm Design, Addison-Wesley, 2005.

Michael Mitzenmacher and Eli Upfal, Probability and Computing, Cambridge University Press, 2005.

David Williamson and david Shmoys, The Design of Approximation Algorithms,Cambridge University Press, 2011.

Fedor Fomin and Dieter Kratsch, Exact Exponential Algorithms,
Springer, 2010.

SI 530 Statistical Quality Control 2 1 0 6

Total quality control in an industry. Quality planning, quality conformance, quality adherence. Quality assurance and quality management functions.

Control charts and allied techniques. Concept of quality and meaning of control. Concept of inevitability of variation-chance and assignable causes. Pattern of variation. Principles of rational sub-grouping. Different types of control charts. Concept of process capability and its comparison with design specifications, CUSUM charts. Acceptance sampling. Sampling inspection versus 100 percent inspection. Basic concepts of attributes and variables inspection. OC curve, Single, double, multiple and sequential sampling plans, Management and organisation of quality control.

Texts / References

A.J. Duncan, Quality Control and Industrial Statistics, 5th ed., Richard D. Irwin, 1986.

E.L. Grant and R. Levenworth, Statistical Quality Control, 6th ed., McGraw-Hill, 1988.

J.M. Juran and F. M. Grayna, Quality Planning and Analysis, Tata McGraw-Hill, 1970.

D.C. Montgomery, Introduction to Statistical Quality Control, Wiley, 1985.

T.P. Ryan, Statistical Methods for Quality Improvement, Wiley, New York, 2000.

SI 532 Statistical Decision Theory 2 1 0 6

Prerequisite : MA 577

Decision functions, Risk functions, utility and subjective probability, Randomization, Optimal decision rules. Admissibility and completeness, Existence of Bayes Decision Rules, Existence of a Minimal complete class, Essential completeness of the class of non-randomized rules. The minimax theorem.

Invariant statistical decision problems. Multiple decision problems.

Sequential decision problems.

Texts / References

J.O. Berger, Statistical Decision Theory : Foundations, Concepts and Methods, Springer-Verlag, 1980.

J.O. Berger, Statistical Design Theory and Bayesian Analysis, 2nd ed., Springer-Verlag, 1985.

T.S. Ferguson, Mathematical Statistics, Academic Press, 1967.

S.S. Gupta and D. Huang, Multiple Statistical Decision Theory, Springer-Verlag, New York, 1981.

SI 534 Nonparametric Statistics 2 1 0 6

Prerequisite: SI 402, Statistical Inference

Kolmogorov-Smirnov Goodness-of – Fit Test.

The empirical distribution and its basic properties. Order Statistics. Inferences concerning Location parameter based on one-sample and two-sample problems. Inferences concerning Scale parameters. General Distribution Tests based on Two or More Independent Samples.

Tests for Randomness and equality of distributions. Tests for Independence. The one-sample regression problem.

Asymptotic Relative Efficiency of Tests. Confidence Intervals and Bounds

Texts / References

W.W. Daniel, Applied Nonparametric Statistics, 2nd ed., Boston: PWS-KENT, 1990.

M. Hollandor, and D.A. Wolfe, Non-parametric Statistical Inference, McGraw-Hill, 1973.

E.L. Lehmann, Nonparametric Statistical Methods Based on Ranks, McGraw-Hill, 1975.

J.D. Gibbons, Nonparametric Statistical Inference Marcel Dekker, NewYork, 1985

R.H. Randles and D.A. Wolfe, Introduction to the Theory of Nonparametric Statistics,Wiley, New York, 1979.

P. Sprent, Applied Nonparametric Statistical Methods**,** Chapman and Hall, London, 1989

B.C. Arnold, N. Balakrishnan and H. N. Nagaraja, First Course in Order Statistics. John Wiley, NewYork, 1992

J.K. Ghosh and R.V. Ramamoorthi, Bayesian Nonparametrics, Springer Verlag, NY, 2003.

SI 536 Analysis of Multi-Type and Big Data 3 0 0 6

Prerequisites: SI 505, SI515.

Overview of Spatial Data, Structured Data. Structural Equation Modeling.

Introduction to Big Data. Large dimension small size multivariate data analysis; tackling the problems of estimation and inference. Classification of Big Data; Screening and Variable Selection.

Lasso Regression; Projection Methods.

Introduction to Markov Chain Monte Carlo (MCMC) Simulations; MCMC techniques for Bayesian Modeling of Big Data.

Text/Ref:

Bollen K.A. *Structural Equations with Latent Variables*, New York: John Wiley, 1989.

Bollen K.A. *Latent Curve Models: A Structural Equation Perspective*. Hoboken: John Wiley, 2006.

Hastie, T., Tibshirani, R. and Friedman, J. *The Elements of Statistical Learning*. Berlin: Springer, 2009.

B¨uhlmann, P. and van de Geer, S. *Statistics for High-Dimensional Data: Methods, Theory and Applications*. Berlin: Springer, 2011.

Cressie, N., *Statistics for Spatial Data*, Revised Edition. NJ: Wiley Classics, 2015

Gamerman, D., Hedibert, F. L. *Markov Chain Monte Carlo: Stochastic Simulation for Bayesian Inference*, 2nd ed. FL: Chapman and Hall/CRC, 2006.

Lecture Notes based on selected recent papers on Big Data Modeling and Analysis.

SI 542 Mathematical Theory of Reliability 2 1 0 6

Pre-requisites: SI 402 Statistical Inference

Coherent Structures, Reliability of systems of independent components, Bounds of system reliability, shape of the system reliability function, notion of ageing, parametric families of life distributions with monotone failure rate, classes of life distributions based on notions of ageing, classes of distributions in replacement policies. Limit distributions for series and parallel systems. Statistical inferential aspects for (i) standard reliability models, (ii) parametric and non-parametric classes of aging distri-butions.

Texts / References

H. Ascher and H. Feingold, Repairable Systems Reliability: Modeling, Inference, Mis-conceptions and Their Causes, Marcel Dekker, 1984.

L.J. Bain and M. Engelhardt, Statistical Analysis of Reliability and Life Testing Models: Theory and Methods, Marcel Dekker, New York, 1991.

R.E. Barlow and F. Proschan, Statistical Theory of Reliability and Life Testing, Holt, Reinhart and Winston, 1975.

J.D. Kalbfleisch and R.L. Prentice, The Statistical Analysis of Failure Time Data, Wiley, 1986.

J.F. Lawless, Statistical Models and Methods for Life Time Data, John Wiley & Sons, 1982.

S.K. Sinha, Reliability and Life Testing, Wiley Eastern, New Delhi, 1986