COURSES OF STUDY 2009

DEPARTMENT OF MATHEMATICS

PROGRAMMES: M.Sc. (Applied Statistics & Informatics)
## COURSE CURRICULA

### M.Sc. (Applied Statistics and Informatics)

#### First Year

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Course Name</th>
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#### List of Elective Courses - Semester III

**Elective I**
- MA 419  Basic Algebra
- SI 503  Categorical Data Analysis

**Elective II**
- MA 417  Ordinary Differential Equations
- SI 505  Multivariate Analysis

**Elective III**
- MA 533  Advanced Probability
- SI 528  Biostatistics
- SI 511  Computer Aided Geometric Design
- SI 515  Statistical Techniques in Data Mining
- SI 525  Testing of Hypothesis

#### List of Elective Courses - Semester IV

**Elective IV**
- SI 512  Finite Difference Methods for Partial Differential Equations
- SI 526  Experimental Designs

**Elective V & VI**
- SI 508  Network Models
- SI 534  Nonparametric Statistics
- SI 513  Theory of Sampling
- SI 530  Statistical Quality Control
- SI 501  Topics in Theoretical CS
- SI 514  Statistical Modeling
- SI 527  Introduction to Derivative Pricing
- SI 532  Statistical Decision Theory
- SI 540  Stochastic Programming and Applications
- SI 542  Mathematical Theory of Reliability
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.


Texts / References


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


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


MA 401 Linear Algebra 3 1 0 8

Systems of linear equations: matrices and elementary row operations, Gaussian elimination, LU decomposition.

Vector Spaces: subspaces, bases and dimension, coordinates.

Linear Transformation: representation of linear transformations by matrices, rank-nullity theorem, duality and transpose, determinants.

Eigenvalues and Eigenvectors: minimal and characteristic polynomials, Diagonalization, Schur's theorem, Cayley Hamilton theorem, Jordan Canonical form.

Inner Product spaces: Gram-Schmidt orthogonalization, reflectors, QR decomposition using reflectors, least squares problem, adjoint of an operator, unitary operators, rigid motions, positive (semi) definite matrices, minimum principles and Rayleigh quotients, matrix norms, condition numbers.

Eigenvalue computation: power and inverse power methods, QR method.

Texts / References


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.


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


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

**Texts / References**


**MA 419 Basic Algebra 2 1 0 6**

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

Permutations, sign of a permutation, inversions, 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**


MA 533 Advanced Probability Theory 2106

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


SI 402 Statistical Inference 3108

Prerequisites: MA 411
MA 438 (Exposure)


Sequential Estimation, Sequential Probability, Ratio Test.

Texts / References


SI 404 Applied Stochastic Process 2106


Applications to queuing models and reliability theory.


Texts / References


SI 415  Introduction to Computer Architecture and Operator Systems

Introduction to the following topics: computer systems, CPU architecture (memory, registers, addressing, busses, instruction set), data representation, peripheral devices, multi-processor systems, operating systems (process, memory management, virtual storage, file systems), basic network components and topologies.

Texts / References


SI 416  Optimization


Constrained optimization (Penalty methods, Lagrange multipliers, Kuhn-Tucker conditions. Linear programming (Simplex method, Dual simplex, Duality theory). Modeling for Optimization.

Texts / References


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

SI 417  Introduction to Probability Theory


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


SI 418  Advanced Programming and Unix Environment

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.brucieckel.com/javabook.html


**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**


**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**


**SI 4xx Data Structures 3 1 0 8**


**Texts / References**


SI 501 Topics in Theoretical Computer Science  2106

Introduction to Complexity Theory (P, NP, NP-hard, NP-complete etc.). Automata Theory and Formal Languages (finite automata, NFA, DFA, regular languages, equivalence of DFA and NFA, minimization of DFA, closure properties of regular languages, regular grammars, context free grammars, parse-trees, Chomsky Normal Form, top-down parsing).

Randomization and Computation (Monte Carlo and Las Vegas algorithms, Role of Markov and Chebyscheff's inequalities, Chernoff bounds in randomized algorithms, applications of probabilistic method).

Special Topics in Theoretical Computer Science, such as Approximation Algorithms, Number Theoretic Algorithms, Logic and Computability.

Texts / References


J. Hein, Discrete Structures, Logic and Computability, Jones and Barlett, 2002.


SI 503 Categorical Data Analysis  3108


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

SI 505 Multivariate Analysis  3108

Prerequisites: SI 402 statistical Inference


Distribution theory associated with the analysis.

Texts / References

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


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


SI 508 Network Models 2 1 0 6

Recap of Linear Programming and duality. Transportation and Assignment. Maximum flow and minimum cut (duality, Ford and Fulkerson algorithm, polynomial time algorithms).

Minimum Cost Flows (cycle cancelling algorithms, successive path algorithms). Matching (bipartite matching, weighted bipartite matching, cardinality general matching).

Routing algorithms (Bellman Ford algorithm in computer networks, Dijkstra's algorithm in computer networks), Application of network models.

Texts / References


SI 509 Time Series Analysis 2106

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.


ARMAX, ARIMAX models and introduction to ARCH models.

Multivariate Time Series, State Space Models.

Texts / References

SI 511 Computer-Aided Geometric Design 2106


Texts / References

SI 512 Finite Difference Methods for Partial Differential Equations 2106

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


SI 513 Theory of Sampling  2 1 0 6

Simple random sampling. Sampling for proportions and percentages.


A brief introduction to randomized response techniques and small area estimation

**Texts / References**


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**


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.


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.


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.


SI 525 Testing of Hypothesis 2 1 0 6

Prerequisites: SI 402 Statistical Inference

Statistical hypotheses, Neyman-Pearson fundamental 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


SI 526 Experimental Designs 2 1 0 6

Prerequisites: SI 402 Statistical Inference


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.


SI 527 Introduction to Derivative Pricing 2 1 0 6

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


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


SI 528 Biostatistics 2106

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


SI 530 Statistical Quality Control 2106

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

**Texts / References**


**SI 532 Statistical Decision Theory 2106**

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**


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

**SI 534 Nonparametric Statistics 2106**

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.


Asymptotic Relative Efficiency of Tests. Confidence Intervals and Bounds

**Texts / References**


J.D. Gibbons, Nonparametric Statistical Inference Marcel Dekker, New York, 1985


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**SI 540 Stochastic Programming and Applications**


**Texts / References**


V.V. Kolbin, Stochastic programming, D. Reidel Publications, Dordrecht, 1977


**SI 542 Mathematical Theory of Reliability**

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 distributions.

**Texts / References**


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). Introduction to NP-Completeness (polynomial time reductions, verification algorithms, classes P and NP, NP-hard and NP-complete problems). Selection of some of the following topics: 1. Randomized algorithms-Monte Carlo and Las Vegas algorithms, Role of Markov and Chebyshev's inequalities, Chernoff bounds in randomized algorithms, applications of probabilistic method, 2. Approximation Algorithms for NP Hard problems, 3. Semi definite programming based algorithms

Texts / References


# Syllabus of new courses

**M.Sc. (Applied Statistics & Informatics)**

| I | Title of the course | Applied Algorithms  
(Proposed Course Number: SI 5XX ) |
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| iii | Prerequisite, if any  
(for the students) | Nil |
| iv | Course content  
(Separate sheet may  
be used, if necessary) | 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). Introduction to NP-Completeness (polynomial time reductions, verification algorithms, classes P and NP, NP-hard and NP-complete problems). Selection of some of the following topics: 1. Randomized algorithms-Monte Carlo and Las Vegas algorithms, Role of Markov and Chebyscheff's inequalities, Chernoff bounds in randomized algorithms, applications of probabilistic method, 2. Approximation Algorithms for NP Hard problems, 3. Semi definite programming based algorithms |
| v | Texts / References  
(Separate sheet may  
be used, if necessary) | J. Kleinberg and E. Tardos, Algorithm Design, Addison-Wesley, 2005.  
| vi | Instructor)(s) name | M.K. Srinivasan and  
S. Sivaramakarishnan |
| vii | Name of other  
Departments to whom  
The course is relevant | Computer Science and Engineering |
| viii | Justification | |
|   | Title of the course | **Data Structures**  
(Proposed Course Number: SI 4XX) |
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| iv | Course content  
(Separate sheet may be used, if necessary) | 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. |
| v  | Texts / References  
(Separate sheet may be used, if necessary) | R. Sedgewick, Algorithms in C, Addison-Wesley, 1992.  
| vi | Instructor(s) name  | M.K. Srinivasan and S. Sivaramakrishnan |
| vii| Name of other Departments to whom The course is relevant | Computer Science and Engineering |
| viii| Justification | |