Elective Courses for Even (Second and Fourth) Semesters

MAT 02E: Relativity

Unit 1. Special Relativity: Inertial Frames of reference, Michelson-Morley experiment, Doppler effect, Stellar aberration, Simultaneity, Postulates of special relativity, Lorentz transformation, Length contraction, Time dilation, Clock paradox, Addition of velocities and accelerations, Four-dimensional space time, Light cone, Mass variation, Velocity four vector, Momentum and force, Mass-Energy relationship.

Unit 2. General Relativity: Geodesics, Geodesic coordinates, Curvature tensor and its algebraic properties, Bianchi's identities, Contracted curvature tensor, Conditions for a flat space time, Displacement of space –time, Killing equations, Groups of motion, Space –time of constant curvature.

Unit 3. Principal of covariance, Non-inertial frames of reference, Principal of equivalence, Weak field approximation of geodesic equations, Law of gravitation in empty space-time, Canonical coordinates, Schwarzschild solutions.

Unit 4. Experimental tests of general relativity, Schwarzschild metric in isotropic coordinates, Brikhoff's theorem, Law of gravitation in non-empty space time.

Unit 5. Energy-Momentum tensor for a perfect fluid, Poisson's equation as the weak field approximation, Schwarzschild interior solution, Gravitational collapse of a ball. Einstein-Maxwell equations of electromagnetism, Gravitational field of a point charge.

Books Recommended:

1. D.F. Lawden: An Introduction to tensor calculus and relativity,
2. J.V. Narlikar: General relativity and cosmology.
3. R.H. Good: Basic concept of relativity, 1978.
4. A.S. Eddington: Mathematical theory of relativity, 1981.

MAT 04E: Riemannian Geometry

Unit 1. Dual vector Spaces : N-dimensional real vector space, Covariant vectors, Dual space, Contravariant vectors, tensor product, Other tensors of second order, Tensors of type (r,s). Algebraic Operations on tensors: Symmetric and skew symmetric properties, Fundamental algebraic operations, Inner product of vectors, Euclidean vector space.

Unit 2. Tensor Calculus : Differentiable manifold, Lie-bracket,Tangent space, Connexions, Covariant derivatives, Curvature tensor, Parallelism. Lie derivative, Exterior derivative, Cartan's structural equations.

Unit 3. Riemannian geometry : Riemannian metric, Christoffel symbols, Curvature tensor with respect to Christoffel symbols, Differential operators, Geodesics, Geodesic coordinates, Riemannian curvature, Conformal curvature tensor, Frenet's formulae.

Unit 4. Ricci's Coefficients of Rotation : Orthonormal basis, Curl of a congruence, Canonical congruences, Gaussian and Ricci curvature.

Unit 5. Sub-manifolds and Hypersurfaces : Normals, Gauss's formulae, Weingarten equations, Coordinate viewpoint, Lines of curvature, Generalized Gauss and Mainardi-Codazzi equations.

Books Recommended:

1. R.S. Mishra: A Course in tensors with applications to Riemannian Geometry, Pothishala Pvt. Ltd., Allahabad, 1965.
2. K. Yano: The theory of Lie derivatives and its applications, North-Holland Publishing Company, Amsterdam, 1957.
3. Matthew S. Smith: Principal and Application of Tensor Analysis, W. Sons (Indianapolis) 1963.
4. N. J. Hicks: Notes on differential geometry, Van Nostrand publishing.

5. H.S. Shukla, Prasad & Dhruwa Narain Dubey: Differential Geometry of Manifolds, Vandana Prakashan, Mohanlalpur, Gorakhpur.

MAT 06E: Advanced Abstract Algebra

Unit 1. Modules over a ring. Endomorphism ring of an abelian group. R – Module structure on an abelian group M as a ring homomorphism from R to End_z {M}. Submodules. Direct summands. Annihilators. Faithful modules. Homomorphism. Factor modules. Correspondence theorem, Isomorphism theorems.

Unit 2. $Hom_R[M,N]$ as an abelion group and $Hom_R[M, M]$ as a ring. Exact sequences. Five lemma. Products, coproducts and their universal property. External and internal direct sums.

Unit 3. Free modules. Homomorphism extension property. Equivalent characterisation as a direct sum of copies of the underlying ring. Split exact sequences and their characterisations. Projective modules. Injective modules. Divisible groups. Examples of injective modules. Boolean Algebra.

Unit 4. Factorisation of polynomials in extension fields. Splitting fields and their uniqueness. Seperable field extensions. Perfect fields. Seperability over fields of prime characteristic. Transitivity and seperability. Automorphism of fields. Dedekind's theorem. Fixed fields. Normal extensions. Splitting fields and normality. Normal closures.

Unit 5. Galois extensions. Fundamental theorem of Galois theory. Computation of Galois groups of polynomials.

Books Recommended:

1. F.W. Anderson and K.R.Fuller: Rings and Categories of Module, Springer N.Y.
2. N.S. Gopalkrishnan: University Algebra,Wiley Eastern Ltd., New Delhi.
3. D.S. Malik, J. N. Mordeson, and M.K. Sen: Fundamentals of Abstract Algebra, McGraw-Hill International Edition, 1997.
4. Vivek Sahai, and Vikas Bisht: Algebra, Narosa Publishing House 1999.
5. P. B. Bhattacharya, S. K. Jain and S.R. Nagpal: Basic Abstract Algebra (2^{nd} Edition), Cambridge University Press, Indian Edition 1977 .
6. I. N. Herstein: Topics in Algebra, Wiley Eastern, 1963.

MAT 08E: Operations Research

Unit 1. Basics of OR and LPP: Development of OR, Definition, characteristics, scope, objectives and limitations of OR, Formulation of LPP, Graphical Method to solve LPP, General LPP, Canonical and Standard forms, Properties of Solutions and Theory of Simplex method, Big M Method and Two phase simplex method, Degeneracy in LPP. Duality in LPP, Duality and simplex method, Dual simplex method, Revised simplex method and bounded variable problems.

Unit 2. Transportation and assignment Models: Lp Formulation of TP, Transportation Table, Finding initial basic feasible solution, Test of optimality, Degeneracy, MODI method, Stepping Stone method, Solutions of Assignment problems, Hungerian method, Duality in assignment problem.

Unit 3. Sensitivity Analysis: Changes in Objective Function Coefficient, Changes in constants, Changes in coefficients of decision variables in constraints, Structural changes.

Unit 4. Integer and Dynamic Programming: Pure and Mixed integer programming, Gomory all IPP method, Fractional cut method, Branch and bound method, Dynamic programming: Recursive equation approach, dynamic programming algorithm.

Unit 5. Network Analysis and Nonlinear Programming: Network flow problem, minimal spanning tree problem, shortest rout problem, maximal flow problem, minimum cost flow problems, critical path analysis, PERT and CPM, Formulation of NLPP, general NLPP, constrained optimization with equality and unequality constraints.

Books Recommended:

1. H. A. Taha: Operations Research, An Introduction, Pearson.

2. Kanti Swarup, P K Gupta, Manmohan: Operations Research, Sultan Chand & Sons, New Delhi.
3. S.S. Rao: Optimization Theory and Applications Wiley Eastern.
4. F. S. Hiller and G. J. Leiberman: Introduction to Operation Research (6th Edition), McGraw-Hill International Edition, 1995.

MAT 10E: Statistical Analysis

Unit 1. Statistical Inference: Concept of consistency, efficiency, sufficiency, unbiasedness, and completeness. Existence of best asymptotically, normal estimates under regulatory conditions . Maximum likelihood and other methods of estimation. Properties of maximum likelihood estimates. Minimax and Baye's estimates. Interval estimation: Neyman's Approach. Best confidence intervals.

Unit 2. Testing of Hypothesis: Simple and composite hypothesis, critical region, two types of errors, level of significance and power of a test. Most powerful test and uniformly most powerful test.

Unit 3. Neyman and Pearson's lemma. Likelihood Ratio tests. Large sample test. Sampling distribution of mean and variates. Exact sampling distributions: t, F and Z distributions and tests of significance based on them. Chi square distribution and its applications. Non parametric tests. Analysis of variance and covariance. Gauss – Markov models. Fixed, random and mixed effect models.

Unit 4. Simple and multiple linear regression . Elementary regression diagnostics. Logistic regression.
Unit 5. Hazard function and failure rates. Censoring and life testing series and parallel systems.

Books Recommended:

1. *J. Medhi: Stochastic Processes, Wiley Eastern Ltd.*
2. *H.C. Saxena & P.U. Surendran: Statistical Inference, S. Chand & Co.*
3. *H.C. Saxena: Mathematical Statistics .*
4. *S.C. Gupta & V.K. Kapoor: Fundamentals of Mathematical Statistics, Sultan Chand & Co.*
5. *S.K. Sinha: Reliability & Life Testing.*

MAT 12E: Theory of Computation

Unit 1. Introduction: Basics of automata theory- Alphabet, strings, closures, languages. Principle of mathematical induction, Inductive proof, Pigeonhole principle.

Unit 2. Finite automata: Definitions, states and transitions, Deterministic finite automata (DFA), Notations for DFA, Transition diagrams, String processing with DFA, The language of DFA, Non-deterministic finite automata (NFA), Notations for NFA, Equivalence of DFA and NFA, FA with epsilon-transitions, Conversion of NFA into DFA, Minimization of states in DFA, Text search using FA- a case study.

Unit 3. Regular Expressions and regular languages: Regular Expressions (RE), Operators of RE, Operator precedence of RE, Finite automata and RE, Conversion of DFA into RE, Converting RE to automata, Algebraic laws for RE- associative, commutative, distributive, idempotent laws, closures. RE and regular languages (RL), Properties of RL, Pumping lemma and its applications, Testing emptiness of RL, testing membership of RL, testing equivalence of RL, RL and FA.

Unit 4. Context free grammar (CFG) and Language (CFL): Definitions, Derivations using grammar, leftmost and rightmost derivatives, The language of grammar, Sentential forms. Parse trees, yields of parse trees, Ambiguity in grammars, Multiple parse trees, Removal of ambiguity, Inherent ambiguity. Properties of CFG- Normal forms, Elimination of useless symbols, elimination of epsilon-productions and unit productions, Chomsky normal form. Pumping lemma for CFL, Closure properties of CFL.

Unit 5. Push Down Automata (PDA): Definitions, Notations of PDA, Transitions function and Instantaneous description, The language of PDA, Acceptance by final state, Acceptance by empty stack.
Practical assignments: Based on topics included in the paper.

Books Recommended:

1. K. L. P. Mishra & N. Chandrasekaran: Theory of computer science, PHI.
2. H. Rosen, Kenneth: Applied Discrete Structure for computer science, Galgotia Publication.
3. Gersting: Mathematical Structucture for computer science, WH Freeman and Macmillan.
4. C. L. Liu: Elements of Discrete Mathematics, McGraw Hill.

MAT 14E: Design and Analysis of Algorithms

Unit 1. Basics of algorithms and analysis: Algorithms, Basic notations, Complexity, Asymptotic notations, Models of computation for algorithms design (RAM and PRAM). Recurrence relations and algorithms, Problem solving approaches: divide and conquer, greedy methods, dynamic programming, backtracking, branch and bound.

Unit 2. Computational algorithms: Order statistics (k-order statistics), Dictionary and Priority queues, Mergeable heaps; Hashing: hash function, hashing by chaining, direct access table, open hashing.
Unit 3. Divide and Conquer Algorithms and graphs: Definitions, General characteristics, Matrix multiplication, convex hull.

Unit 4. Greedy Algorithms: Minimum cost spanning trees (Kruskal's and Prim's algorithms), Shortest path finding (Dijkstra's algorithm), scheduling with deadlines, Huffman coding.

Unit 5. Dynamic Programming: Principle of optimality, knapsack problem, matrix chain multiplication. P and NP problems: Basic Terminology, Computational complexity, tractable and intractable problems. Parallel algorithms: Parallel sorting networks, even odd sorting network .
Practical assignments: Based on topics included in the paper.

Books Recommended:
1. Jon Kleinberg & Eva Tardos: Algorithm design.
2. Horowitz Sahani: Fundamental of Computer Algorithm, Galgotia.
3. Coreman Leiserson et al: Introduction to Algorithm, Prentice Hall of India.
4. Brassard Bratley: Fundamental of Algorithm, Prentice Hall of India.
5. M.T. Goodrich et al: Algorithms Design, John Wiley and Sons.
6. A.V. Aho et al: The Design and Analysis of Algorithms, Pearson Education.

MAT 16E: Coding Theory

Unit 1. Introduction: Basic information theory (incl. entropy, channel models), Algebraic coding theory (incl. linear block codes, cyclic codes), The q-ary symmetric channel, Maximum-likelihood decoding , Error correction, error detection, and erasure correction.

Unit 2. Linear codes: Representation through generator and parity-check matrices, Syndrome decoding, Hamming codes.

Unit 3. Introduction to finite fields and double-error-correcting codes: Irreducible polynomials, Primitivity, Double-error-correcting codes.

Unit 4. Bounds on the parameters of codes: The Singleton bound; MDS codes, The Hamming sphere-packing bound; perfect codes , Generalized Reed-Solomon (GRS) codes, BCH codes and alternant codes as subfield subcodes of GRS codes, Concatenated codes , Decoding GRS codes using Euclid's algorithm.

Unit 5. Structure of finite fields and cyclic codes: Minimal polynomials, Cyclic codes, BCH codes as cyclic codes, The BCH bound.

Books recommended:
1. *R. E. Blahut:* Theory and Practice of Error-Control Codes. *Reading, MA: Addison-Wesley, 1983.*
2. *F. J. MacWilliams and N. J. A. Sloane:* The Theory of Error Correcting Codes. *Amsterdam, Netherlands, North-Holland, 1978.*
3. *J. H. Van Lint:* Introduction to Coding Theory, *3rd ed. Berlin, Germany, Springer-Verlag, 1999.*

MAT 18E: Dynamical Systems

Unit 1. One Dimensional Dynamics: Examples of dynamical systems, Preliminaries from calculus, elementry definitions, Hyperbolicity, An example from quadratic family, symbolic dynamics.

Unit 2. Topological conjugacy, Chaos, structural stability, Sarkovskii's theorem, The Schwrzian derivative, Bifurcation theory.

Unit 3. Complex Analytic Dynamics: Preliminaries from complex analysis, The Riemann sphere, Steriographic projection, Examples from quadratic maps.

Unit 4. Equicontinuity and normal families, Montel's Theorem, Julia and Fatou sets, Fixed and periodic points and their classification.

Unit 5. Critical points, Exceptional points, Properties of Julia sets, Mandelbrot set.

Books Recommended:

1. R. L. Devaney: An Introduction to Chaotic Dynamical Systems, Addison- Wesley.
2. A. F. Beardon: Iteration of Rational Functions, Springer- Verlag.
3. C. G. Carlson and T. W. Gamelin: Complex Dynamics, Universitext, Springer.
4. R. A. Holmgren: A first course in discrete dynamical systems, Springer.