INSTITUTE OF MATHEMATICS AND APPLICATIONS

COURSES OF STUDIES

B.SC. (HONS.)
(IN MATHEMATICS AND COMPUTING)

(w.e.f. 2018-19)

UTKAL UNIVERSITY
BHUBANESWAR-751004

B.Sc.(H) IN MATHEMATICS AND COMPUTING

Regulations:

1. A candidate seeking admission to this programme should have passed Higher Secondary or equivalent examination with mathematics as a subject.
2. The duration of the programme is three years consisting of six semesters. Ordinarily the odd semester examinations shall be held in December and the even semester examinations shall be held in the month of in April.
3. The programme shall have choice based credit system with internal valuation.
4. A student who has been admitted into this programme can register in a semester examination if he has obtained 75% (subject to a condonation of 15% in case of ailment) of attendance in the theory and a practical class of that semester and pays the required fees of the University.
5. Each semester examination shall consist of two parts: mid semester tests and end semester examination having weightage of 30% and 70% respectively for each course.
6. The questions in each paper shall be set in such a way that a student needs to answer one question from each unit of the syllabus of that paper.
7. In order to pass a course a candidate has to secure at least 4 or above grade points in 10 points scale.
8. For passing a semester examination a candidate must pass in each course of that semester.
9. If a candidate passes all the semester examinations he/she shall be declared to have passed the B.Sc. (H) in Mathematics and Computing.
   i. In first class if he /she secures a total grade points average 6 or above.
   ii. In second class if he/she secures 4.5 or more but less that 6 of grade point average.

Total grade point average ≡ sum of credit times grade point obtained divided by sum of credit. ($\Sigma c_i s_i$ / Σc_i) where c_i = course credit, s_i = grade point obtained and grade point of a course is calculated as follow.

Marks obtained in course	Grade point secured
90% or above	10
80% or above and less than 90%	9

70% or above and less than 80%	8
60% or above and less than 70%	7
50% or above and less than 60%	6
40% or above and less than 50%	5
35% or above and less than 40%	4
Below 35%	0(Fail)

Candidate securing 5 or above grade point average in courses other than Mathematics and Computing shall be declared to have passed with distinction, i.e. the courses Communication English, Probability-I/Econometrics, Environmental Studies, Probability–II, Statistics-I & II, Mechanics/Quantum Mechanics/Electrodynamics/Relativity and Gravitation, Bio-Mathematics (Bio-Informatics)/Data Analytics shall constitute the courses for deciding the award of distinction.

Explanatory Note:

Since the course is B.Sc. (H)in Mathematics and Computing there is no scope for pass degree without Honours. In these regulations the terms 'Paper' and 'Course' mean the same thing.

10. If a candidate fails in any course (or courses) in any semester examination he /she has to appear the end semester examination for that course (or courses) only whenever the said semester examination is held. Passing the said semester examination is governed by regulation 8 and 9 above.
11. A candidate who has passed a semester examination and wants to improve the results may appear only once for a maximum of three courses of that semester examination within a period of one year of passing the said semester examination. The higher of the grade points secured shall be taken into consideration for determining the result.
12. The candidate has to pass all the semester examinations within four academic years from the date of admission failing which his admission to the course will be cancelled.

DRAFT COURSE STRUCTURE FOR
B.Sc.(H) IN MATHEMATICS AND COMPUTING
INSTITUTE OF MATHEMATICS AND APPLICATIONS, BHUBANESWAR

In the following C stands for no. of credits for the paper; Th, Pr and Tu respectively stand for no. of theory classes, practical classes and tutorial classes per week.

		C	Th	Pr	Tu
CORE COURSES (COMPULSORY)					
Core-1	Calculus-I	6	5+		1= 6
Core-2	Algebra-I (Matrix Theory)	6	5+		1= 6
Core-3	Computer Science-I (Introduction to Programming and Data Structure+ Lab)	4+	2		= 6
Core-4	Calculus-II	6	5+		1= 6
Core-5	Algebra-II (Group Theory)	6	5+		1=6
Core-6	Calculus-III	6	5+		1= 6
Core-7	Algebra-III (Rings and Fields)	6	5+		1=6
Core-8	Differential Equations with modelling	6	5+		1= 6
Core-9	Differential Equations-II(PDE)	6	5+		1= 6
Core-10	Algebra-IV (Linear Algebra)	6	5+		1= 6
Core-11	Complex Analysis	6	5+		1= 6
Core-12	Number Theory-I	6	5+		1=6
Core-13	Numerical Analysis with Lab.	6	4+		2= 6
Core-14	Differential Geometry	6	5+		1= 6
ABILITY ENHANCEMENT COMPULSORY COURSES(AECC)					
AECC-I	Communication English	2	2		= 2
AECC-II	Environmental Studies	2	2		= 2

GENERIC ELECTIVES COURSES - GEC (One Elective paper to be chosen from each group)

GEC-I

1. Combinatorics and Discrete Mathematics	6	5+		1=6
2. Cryptography	6	5+		1=6

GEC-II

1. Computer Science-II (Design and Analysis of Algorithms +Lab)	6	4+	2=6	
2. Coding Theory	6	5+		1=6

GEC-III

1. Probability-I	6	5+	1= 6	
2. Econometrics	6	5+		1=6

GEC-IV

1. Computer Sciences-III (Computer Organization & Operating System)	6	5+		1=6
2. Statistics-I	6	5+		1=6

GEC-V

1. Computer Science-IV (Database Management System+Lab)	6	5+		1=6
2. Topology	6	5+		1= 6
3. Finite Element Methods	6	5+		1= 6
4. Algebraic Geometry	6	5+		1=6

GEC-VI

1. Computer Science-V(Theory of Computation)	6	4+		2=6
2. Statistics-II	6	5+		1=6
3. Functional Analysis	6	5+		1=6
4. Lie Algebras and Group Representations	6	5+		1= 6

GEC-VII

1. Mechanics	6	5+		1= 6
2. Quantum Mechanics	6	5+		1=6
3. Electrodynamics	6	5+		1=6
4. Relativity and Gravitation	6	5+		1=6

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE (One Elective paper to be chosen from each group)

DSE-I

1. Applications of Algebra	6	5+	1= 6
2. Portfolio Optimization	6	5+	1=6
3. Classical Geometry	6	5+	1=6
4. Theory of Equations	6	5+	1=6

DSE-II

1. Optimization and LPP	6	5+	1=6
2. Industrial Mathematics	6	5+	1=6
3. Soft Computing Methods	6	5+	1=6
4. Artificial Intelligence	6	5+	1=6
5. Discrete Dynamic System	6	5+	1=6

DSE-III

1. Computer Science-VI(Computer Network)	6	5+	1= 6
2. Probability-II	6	5+	1= 6
3. Number Theory-II	6	5+	1=6
4. Bio-Mathematics /Bio-Informatics	6	5+	1=6
5. Data Analytics	6	5+	1=6

DSE-IV

1. Project Work	6

SKILL ENHANCEMENT COURSE - SE (One Elective paper to be chosen from each group)

SE-I

1. Object Oriented Software Engineering	2	2	=2
2. Transportation and Game Theory	2	2	=2
3. Modelling and Simulation	2	2	=2
4. Internet of Things	2	2	=2
5. Parallel Computing	2	2	=2

SE-II

1. Computer Graphics	2	2	= 2
2. Logic and Set Theory	2	2	=2
3. Combinatorial Optimization	2	2	=2
4. Boolean Algebras	2	2	=2
5. Image& Video Processing	2	2	=2

Semester-I

1. Core-1: Calculus-I
2. Core-2: Algebra-I (Matrix Theory)
3. Core-3: Computer Science-I (Introduction to Programming and Data Structure+Lab)
4. Generic Elective-I: Combinatorics and Discrete Mathematics/Cryptography
5. AECC-I: Communication English

Semester-II

1. Core-4: Calculus-II
2. Core-5: Algebra-II (Group Theory)
3. Generic Elective-II: Computer Science-II (Design and Analysis of Algorithms+Lab)/Coding Theory
4. Generic Elective-III: Probability-I/Econometrics
5. AECC-II: Environmental Studies

Semester-III

1. Core-6: Calculus-III
2. Core-7: Algebra-III (Rings and Fields)
3. Core-8: ODE
4. Generic Elective-IV: Computer Science-III (CO&OS)/Statistics-I
5. SE-I: Object Oriented Software Engineering/Transportation and Game Theory/ Modelling and Simulation/ Internet of Things/ Parallel Computing

Semester-IV

1. Core-9: PDE
2. Core-10: Algebra-IV (Linear Algebra)
3. Core-11: Complex Analysis
4. Generic Elective-V: Computer Science-IV(DBMS)/Topology/Algebraic Geometry
5. SE-II: Computer Graphics/ Logic and Set Theory/Combinatorial Optimization / Boolean Algebras/ Image & Video Processing

Semester-V

1. Core-12: Number Theory-I
2. Core-13: Numerical Analysis with LAB
3. DSE-I: Applications of Algebra/Portfolio Optimization/Classical Geometry / Theory of Equations

4. DSE-II: Optimization and LPP/ Industrial Mathematics/ Soft Computing Methods/ Artificial Intelligence/ Discrete Dynamical System
5. Generic Elective-VI: Computer Science-V(Theory of Computation)/Statistics-II/ Functional Analysis/ Lie Algebras and Group Representations

Semester-VI

1. Core-14: Differential Geometry
2. DSE-III: Computer Science-VI(Computer Network)/ Number Theory-II/ Probability-II/Bio-Mathematics (Bio-Informatics)/ Data Analytics
3. DSE-IV: Project Work
4. Generic Elective-VII: Mechanics/ Quantum Mechanics/Electrodynamics/Relativity and Gravitation

Detailed Syllabus

First Year

First Semester

Core-1 Calculus – I — 6 credit

Sets and functions; countable and uncountable sets.

Real numbers: denseness of rationals and irrationals; least upper bounds and greatest lower bounds, the least upper boundaxiom; Archimedean property; countability of rationals, uncountability of reals.

Sequences, convergence and limits; uniqueness of limit, arithmetic of limit, sandwich principle, sub-sequences, existence of limits of bounded and monotone sequences, Bolzano-Weierstrass theorem, limes superior, limes inferior, Cauchy sequences, completeness of **R**.Infinite series, convergence and divergence of series, absolute and conditional convergence of series, various standard tests for convergence of series; the numbers e and e^x; decimal ternary and binary expansion of real numbers.

Real functions of a real variable; some standard examples-Limit of a function at a point, calculating limit of a function through limits of sequences, $\lim_{x\to 0}\frac{\sin x}{x}$. Continuous functions, attainment of maxima/minima and uniform continuity of continuous functions on closed bounded intervals, Intermediate value theorem; composition of continuous functions, change of variable in limit, the exponential function, the nth root function on the positive reals.

Differentiability of a function; Chain Rule; Rolle's theorem and mean value theorem; higher order derivatives; limits of indeterminate forms, maxima and minima; convexity/ concavity of functions, relating convexity/concavity of a graph with the second derivative of the function: Curve tracing using calculus.

Recommended Texts:

1. S.R. Ghorpade&B.V.Limaye: *A course in Calculus and Real Analysis*, Springer.
2. T.M.Apostol: *Calculus vol. 1 & II*
3. W. Rudin: *Principles of Mathematical Analysis*
4. T.*M.*Apostol:*Mathematical Analysis*
5. EM Stein & Rami Shakarchi: *Fourier Analysis: An Introduction*
6. Any text recommended by the Instructor

Core-2 Algebra-I (Matrix Theory) — 6 credit

Linear equations:

Geometric interpretation of solution of systems of equations in two and three variables; matrix notation; solution by elimination and back substitution; interpretation in terms of matrices, elimination using matrices; elementary matrices, properties of operations on matrices.

Inverse of a square matrix:
Definition and uniqueness; non-existence in general: singular matrices; calculation of inverse using Gauss-Jordan elimination; existence of one sided inverse implies invertibility; decomposition of a matrix as product of upper and lower triangular matrices.

Vector spaces, subspaces, and linear equations:
Notion of a vectorspace; subspaces; linear combination of vectors; column and row spaces of an m×n matrix; span; null space of matrix; finding the null space by elimination; the reduced row echelon form of a matrix; complete solution to an inhomogeneous system; dependence of the totality of solutions on the number of nonzero rows of the reduced echelon form.

Linear independence:
Notion of linear independence; bases and dimension; dimensions of the row-space, column space and the null space of an m×n matrix, row and column rank, comparision of row ranks of matrices AB and B and column ranks of BA and B, rank-nullity theorem, dimension of important subspaces of matrices (triangular, diagonal, symmetric, etc.) . Determinants formula for 2×2 and 3×3 matrices; formulas for the determinant: cofactors and Laplace expansion, Cramer's rule for the inverse of a matrix, determinant computes area and volume of rectangles and cuboids; determinant of the product is the product of determinants, equivalence of non-vanishing determinant and invertibility of the matrix.

Orthogonal matrices and rotations:
Orthogonal matrices and rotations in 2 and 3 dimensional spaces.

Introduction to Spectral theory:
Eigenvectors and eigenvalues; characteristic polynomial of a matrix, eigenvalues as roots of the characteristic polynomial; invertible iff zero not an eigenvalue; linear independence of eigenvectors corresponding to different eigenvalues; diagonalizability of an n×nmatrix having n linearly independent eigenvectors; Cayley-Hamilton theorem.

Recommended Texts:

1. Strang, *Introduction to linear Algebra*, 4th ed., Wellesly Cambridge Press, Chapter 1-5, 6.1,6.2.
2. S. Kumaresan, *Linear Algebra*, a geometric approach, PHI.
3. Hoffman and Kunze, Linear Algebra, 2nd ed., PHI. Chapters 1-3,5, 6.1-6.4,8.
4. M.Artin, Algebra, Prentice-Hall of India, Chapters 1,3,4,7.
5. I.N.Herstein, *Topics in algebra*, 2nd edition, 1975, Chapter 6.
6. Any text recommended by the Instructor

Core-3 Computer Science-I(Introduction to Programming and Data Structure+Lab)6 credit

Programming in C: Programming methodology, overview of C, Lexical elements, syntax rules, basic data types, operators, expressions, flow of control, function definitions, conditional execution, loops, arrays, recursion, pointers, strings, preprocessor, linked list, stacks and queues, file input/ output, introduction to C++.

Laboratory components: Execution of simple programmes, conditional and branching, loops, functions, recursions, arrays, structures, linked lists, stacks and queues, use of file input/ output.

Recommended Texts:

1. Brian W. Kernighan and Dennis M. Ritchie: TheC Programming Language.
2. Bruce Eckel: Thinking in C++ (free ebook also available)
3. Byron S. Gottfried: Theory and Problems of Programming with C.
4. A. Kelly, I. Pohl, A book on C, Pearson Education, 2000.
5. Any text recommended by the Instructor

Core-4 Calculus-II — 6 credit

Riemann Integration of a bounded function on a bounded interval, existence for continuous functions; properties of integrals; Fundamental theorem of Calculus; change of variables.Illustration of standard techniques for computing integrals.Application of Riemann integrals for finding areas.Defining functions by integrals; the Log function, the arc tan function. Sequences of functions, uniform convergence, interchange of limit and integral.
The inverse function theorem for a differentiable function. Relating the exponential and the log function. Definition and properties of the functions x^a.
Taylor's expansion with various forms for the remainder, Infinite Taylor'sexpansion, Power Series, radius of convergence; interchange of limit and sum; term-by-term differentiation; term-by term integration. The Taylor series expansion of some standard functions.
The function e^z and periodicity of sine and cosine.
Cauchy Schwarz inequality, Holder's inequality, Minkowski's inequality.Properties of convex functions, Jensen's inequality.
Improper integrals with plenty of examples.Beta and Gamma functions.

Recommended Texts:

1. S. R. Ghorpade& B. V. Limaye : A Coursein Calculus and Real Analysis, Springer.
2. T. M. Apostol : Calculus vol. I & II
3. W. Rudin: Principles of Mathematical Analysis
4. T. M. Apostol : Mathematical Analysis
5. E M Stein & Rami Shakarchi: Fourier Analysis: An Introduction.
6. Any text recommended by the Instructor

Core-5 Algebra-II (Group Theory) — 6 credit

Integers (Review): Well ordering principle in natural numbers; division algorithm; GCD and LCM; Euclid's algorithm: GCD of two integers is a linear combination of them; unique factorization of integers; modular arithmetic ; principle of mathematical induction.
Relations and functions(Review) : Equivalence relations; equivalence classes; partitions; functions; injections; surjections; and bijections.
Symmetrics: Motivation for the definition of a group ; dihedral groups.
Groups: Binary operation on a set; axiomatic definition of a group; examples: these to include general and special linear groups over familiar fields, the group of units of integers modulo n and connection with Euler's ϕ –function.
Elementary properties: Uniqueness of identity and inverse, cancellation, etc; subgroups; order of a group; order of an element ; finite groups.
Homomorphisms, isomorphisms, Normal subgroups, kernels and images; kernels and normal subgroups.Quotientgroups.Conjugation; linear and outer automorphisms;
Cyclic groups: Classification; the structure of subgroups of a cyclic group.
Cosets: Lagrange's theorem; theorems of Fermat and Euler from number theory to be seen as special cases.

Permutation groups: Definition; cycle notation; representation as a product of disjoint cycles; generation by transpositions; sign of a permutation; alternating group. Cayley's theorem.

Group actions on sets: Orbit, stabilizer, transitivity; orbit as a quotient space; orbits form a partition; class equation and its application to continuing problems; nilpotent and solvable groups, p-groups are nilpotent. Cauchy's theorem. Examples of GL(n,R) and its subgroups.

Recommended Texts:

1. Gallian, *Contemporary Abstract Algebra*, 4th edition, Narosa, Chapters 1-11.
2. Artin, *Algebra, Prentice-Hall of India*, Chapters 2,5,6.
3. Herstein, *Topics in algebra*, 2nd edition, 1975, Chapters 1,2.
4. Any text recommended by the Instructor.

Core-6 Calculus-III — 6 credit

Functions of several variables; continuity of functions from $\mathbf{R}^m$ to $\mathbf{R}$ and from $\mathbf{R}^m$ to $\mathbf{R}^n$. Partial derivatives, directional derivatives. Differentiability and derivative as a linear transformation; chain rule, sufficient conditions for differentiability; higher derivatives; stationary points and local maxima and minima. Lagrange's method of multipliers.

Multiple integrals; existence of the multiple Riemann integral for sufficiently well-behaved functions on rectangles; multiple integrals as iterated simple integrals; Brief treatment of Multiple integrals on more general domains; Change of variables and Jacobian formula with lots of illustrations.

Curves in $\mathbf{R}^2$ and $\mathbf{R}^3$; Line integrals. Surfaces in $\mathbf{R}^3$; surface integrals. Divergence, Gradient and Curl operations.

Green's theorem; Stokes' theorem; Gauss'(divergence) theorem. (Proofs only for Cuboids)

Recommended Texts:

1. S.R. Ghorpade& B.V. Limaye: *A Course in Calculus and Real Analysis*, Springer.
2. T.M. Apostol: *Calculus vol. I & II*
3. W.Rudin: *Principles of Mathematical Analysis*
4. T.M.Apostol: *Mathematical Analysis*
5. EM Stein & Rami Shakarchi: *Fourier Analysis: An introduction*.
6. Any text recommended by the Instructor

Core-7 Algebra-III(Rings and Fields) — 6 credit

Part I: Ring Theory

Rings: Motivation, definition, examples, basic properties; subrings. Ideals and factor rings: One-and two-sided ideals; factor rings: prime and maximal ideals in commutative rings: characterization in terms of properties of quotients. Ring homomorphisms: Kernels are ideals; first isomorphism theorem. Zero divisors: Integral domains; fields; finite domains are fields; the finite field Z/pZ.

Field of quotients of an Integral domain. Polynomial ring over a ring: Division algorithm; remainder theorem; polynomial in F[X] of degree n has at most n roots. Principal ideal domains : Z and F[X]; prime ideals an maximal ideals in PIDs.

Factorization of polynomials: irreducible and reducibles; Z[X]: content of a polynomial, primitive polynomials, Gauss's lemma: product of primitives is primitive; primitive and irreducible over Q is irreducible; Irreducibility tests: reading modulo primes; Eisenstein's criterion; cyclotomic polynomials; irreducibility of a polynomial over F[X] being equivalent to it generating a prime ideal; Unique factorization in Z[X].

Part II: FieldTheory

Fields: Axioms; examples. Field extensions: Attaching a root, splitting fields: existence and uniqueness;Multiple roots: The derivative criterion for multiple roots; irreducible polynomials in characteristic zero have no multiple roots. Classification of finite fields solving cubic and quartic equations.

Recommended Texts:

1. Gallian, *Contemporary Abstract Algebra*, 4thedition ,Narosa. Chapters 12-21.
2. Artin, *Algebra*, Prentice-Hall of India, Chapters 10, 11, 13.
3. Herstein, *Topics in algebra*, 2nd edition, 1975.
4. Any text recommended by the Instructor

Core-8 Differential Equations with Modelling — 6 credit

Ordinary differential equations-first order equations, Picard's theorem (existence and uniqueness of solution to first order ordinary differential lequation), second order differential equations-second order linear differential equations with constant coefficients, systems of first order differential equations, equations with regular singular points, introduction to power series and power series solutions, special ordinary differential equations arising in physics and some special functions (e.g. Bessel's functions, Legendre polynomials, Gamma functions).

Recommended Texts:

1. E.A. Coddington, *An introduction to Ordinary Differential equations*, (Prentice Hall).
2. G.F. Simmons, *Differential equations*, (MCGraw Hill).
3. W.Hurewicz: *Lectures on Ordinary Differential Equations* (Dover Publications).
4. Martin Braun, *Differential Equations and their Applications*, Springer.
5. J Sinha Roy and S.Padhy, *Ordinary and Partial Differential Equation*, Kalyani Publisher.
6. G.F.Simmons and J.S.Robertson, *Differential Equations with Applications and Historical Notes*, 2nd Edition, (McGraw Hill).
7. Any book recommended by the Instructor

Core-9 Differential Equations-II (PDE) — 6 credit

Partial differential equations-elements of partial differential equations and the three equations of Physics,i.e. Laplace, Wave and Heat equations, at least in 2 dimensions, Lagrange's method of solving first order quasi linear equations.

Recommended Texts:

1. Fritz John, *Partial Differential Equations*.
2. Phoolan Prasad and RenukaRanindam, *Partial Differential Equations*.
3. Any text recommended by the Instructor

Core-10 Algebra-IV (Linear Algebra) — 6 credit

Vector spaces: Fields and vector spaces; linear combinations; subspaces; span of a set of vectors; linear independence; finite dimensional vector spaces, bases and dimension; coordinates and how they change with choice of basis. Linear transformations definition; linear functionals, composition of transformations; the endomorphism algebra; nvertible transformations; isomorphism: there is only one vector space up to isomorphism of a given dimension; isomorphism: there is only one vector space up to isomorphism of a given dimension; representation of transformations by matrices; correspondence between the algebra of transformations and the algebra of matrices; how the representing matrix changes with choice of bases: similarity transformations; the rank-nullity theorem: row-rank equals column-rank.

Dual Vector Space: The dual V*of a vector space V, dimension of the dual and the dual basis, the double dual and isomorphism of a vector space with its double dual. Linear equations and matrices Revisited in the light of the abstract definition of vector spaces and linear transformations.

Eigenvalues: Review of the material under this heading in the Matrix algebra course: eigenvalues, eigenvectors of a linear transformation, linear independence of eigenvectors corresponding to different eigenvalues, characterstic polynomial. Cayley-Hamilton theorem, minimum polynomial, Jordan canonical form (statement only), similar matrices, use of Jordan form to decide similarity when the field is algebraically closed.

Core-11 Complex Analysis — 6 credit

Complex plane, topology of complex plane, connected open sets in the complex plane, the Riemann sphere.

Analytic functions, Cauchy-Riemann Equations, examples of analytic functions, linear fractional transformations. Power series, radius of convergence, exponential and

trigonometric functions, branches of Logarithm. Complex integration along piecewise smooth curves, Cauchy Integral Formula for a circular arc, power series expansion of analytic functions, Maximum Modulus principle with applications, Zeros of Analytic functions, Maximum Modulus principle with applications, Zeros of Analytic functions, Liouville's Theorem, Proof of Fundamental theorem of Algebra, Winding Numbers, Cauchy's theorem and integral formula. Morera's theorem, Goursat theorem, Isolated Singularities, Removable Singularities, Poles and Essential Singularities, Laurent Expansion around an Isolated Singularity , Residue Theorem. Evaluation of real integrals using Contour integrals.

Recommended Texts:

1. John B. Conway , Functions of one complex variable, Springer.
2. E.M.Stein& Rami Shakarchi, Complex Analysis, Vol.2.
3. T.W.Gamelin, Complex Analysis.
4. R.V. Churchill &J.W.Brown, Complex variables and applications, MCGraw Hill.

Core-12 Number Theory-I — 6 credit

Integer arithmetic and an introduction to Diophantine Equations, Divisibility, greatest common divisors, Euclidean algorithm, Linear Diophantine Equations, Fundamental Theorem of Arithmetic, Special cases of Dirichlet's theorem on infinitely many primes in arithmetical progression such as, primes of the form 4n+3, irrationality of "2, solving the Diophantine equation x2+ y2 = z2 in integers.

Modular Arithmetic:

Introduction to congruences, linear congruences, Chinese Remainder Theorem, Polynomial congruences, systems of linear congruences, factorization using Pollard Rho method, Fermat's little theorem, Wilson's theorem, Euler's theorem, Euler's Phi function, multiplicative functions, sums of divisor function.

Recommended Texts:

1. Kenneth H. Rosen, Elementary Number Theory (and it's applications), Fifth Edition, Pearson Addison- Wesley.
2. D.M. Burton, Elementary Number Theory, 5th Ed. McGraw Hill.
3. H. Davenport, Higher Arithmetic, 7th Ed. Cambridge University Press.
4. G.H. Hardy and E.M. Wright, An introduction totheTheory of Numbers, 5th Ed. Oxford University Press.
5. A. Weil, Number Theory for Beginners, Springer.
6. Koshy, Elementary Number Theory with Applications, Academic Press.
7. Any text recomended by the Instructor

Core-13 Numerical Analysis with Lab. — 6 credit

Nature of numerical computations: Errors and their propagation, convergence and stability of numerical algorithms; efficiency and arithmetic:- complexity. Solution of non linear equations, iterative methods, acceleration of convergence, Newton's methods for polynomials, quotient- difference algorithms. Interpolation and appoximation-interpolating

polynomial and its construction using Lagrangian method and methods of differences, iterated interpolation, method of divided differences, inverse interpolation, spline functions and their use. Numerical integration-Newtonian and Gaussian quadraturemethod, integration formulae using finitedifferences, Romberg integration.Matrix computations-Numerical solutions of systems of linear equations, computation of inverse and eigenvalues of a matrix.Solutions of ordinary differential equations.Programming assignments.

Recommended Texts:

1. K. Atkinsons Numerical Analysis
2. Comte de Boor: Numerical Analysis
3. Any text recommended by the Instructor

Core-14 Differential Geometry 6 credit

Introduction to differential geometry-curves in two and three dimensions, curvature and torsion for space curves, existence theorem for space curves, Serret-Frenet formula for space curves, inverse and implicit function theorems, Jacobian theorem, surfaces in R^3as two dimensional manifolds, tangent space and derivative of maps between manifolds, first fundamental form, orientation of a surface, second fundamental form and the Gauss map, Mean curvature and scalar curvature, integration of surfaces, Stokes formula, Gauss-Bonnet theorem.

Recommended Texts:

1. Do Carmo, Differential Geometry, Academic Press.
2. T.J.Willmore, Differential Geometry.
3. A.N.Pressley, Elementary Differential Geometry, Springer.
4. Any text recommended by the Instructor

ABILITY ENHANCEMENT COMPULSORY COURSES (AECC)

AECC-I Communication English 2 credit

The elements of communication:
The importance of communication through English at the present time.The process of communication and factors that influence communication sender, receiver, channel, code, topic, massage, context, feedback, noice, filters and barriers.The importance of audience and purpose. The information gap principle: given and new information; information overload. Verbal and non-verbal communication: body language. Comparing general communication and business communication.

The sounds of English:
Vowels, diphthongs, consonants, consonant clusters, The International Phonetic Alphabet (IPA): Phonemic transcription, Problem sounds, Syllable division and word stress, Sentence rhythm and weak forms, Contrastive stress in sentence to highlight different words,

Intonation: falling, rising and falling-rising tunes, Varieties of Spoken English: Standard Indian, American and British.

Review and English Grammar:

Stative and dynamic verbs, The auxiliary system: finite and non-finite verbs. Time, tense and aspect, Voice: active and aspect. Modality, Negation, Interrogation: reported and tag questions. Conditionals, Concord, Phrasal verbs.

Phonemic transcription:

Students will be trained to find out the correct pronunciation of words with the help of a dictionary to enable them to monitor and correct their own pronunciation.

1. Transcription of words and short sentences in normal English orthography (writing) into their IPA equivalents
2. Transcription of words presented orally
3. Conversion of words presented through IPA symbols into normal orthography
4. Syllable division and stress making (in word presented in IPA from)

Listening

1. Listening with a focus on pronunciation (era-training): Segmental sounds, stress, weak forms, intonation Students should be exposed, if possible , to the following varieties of English during listening practice Standard Indian, British and American.

Speaking

1. Pronunciation practice(for accent neutralization), particularly of problem sounds, in isolated words as well as sentences
2. Practising word stress, rhythm in sentences, weak forms, intonation
3. Reading aloud of dialogues, poems, excerpts from plays, speechless etc. for practice in pronunciation

Grammar and usage

The focus will be on the elimination of common errors. Some writing activities (e.g. writing of short paragraphs on assigned topics) can be used to identify these errors.

Recommended Texts:

1. An introduction to Professional English and Soft Skills by B.K.Das et al., Cambridge University Press
2. Any text recommended by the Instructor

AECC-II Environmental Studies — 2 credit

Fundamental Concepts:

Study is multidisciplinary, Scope and importance , Public awareness, Earth as an Ecosystem, Concept, Structure and function of ecosystem, Producers, Consumers and Decompisers, Energy flow, Succession, Food chains and food webs, Different ecosystems (Forest, Grassland, Desert, Pond).

Environmental Pollution (Atmosphere and Hydrosphere):

Soil and Freshwater Pollution, Marine Pollution, Air and Noise Pollution, Thermal pollution, Nuclear Hazards, Solid waste management, Role of man in prevention of pollution, Pollution case studies and field visit, Disaster management (Floods, Cyclone), Case Studies.

Lithosphere and Energy Resources:

Human pollution, Environment and public health population growth, Human rights, Value Education, HIV/AIDS, Women and child care, role of IT in environment and human health, case studies.

Public Health:

Natural resources (Renewable and non-renewable), Forest resources (Over-exploitation), Case study and field visit, Water resources, (Use and Over-exploitation of surface and ground water) , Mineral resources, (Use and Over-exploitation and case studies), Food Resources (Food problems, case studies), Role of man in conservation, Equitable use for sustainability, Biodiversity conservation, Value at local and global levels, Hotsports of biodiversity and India, Threats, In-situ and Ex-situ conservation.

Environment, Society and Law:

Social issues and environment: Sustainable development, Urban problems related to energy, rain water harvesting, environmental ethics, climate change, global warming, Ozone depletion, acid rain, nuclear accidents, case studies, Wasteland reclamation, Environment Act, Acts of air, water, wildlife and forest conservation, public awareness.

Recommended Texts:

1. E.J.Kermondy, *Concepts of Ecology*, Prentice Hall, 4th Ed. 1996.
2. V.Subramanian, *A Text Book in Environmental Science*, Narosa Pub. House, 2002.
3. S.C.Bhatia, *Managing Industrial Pollution*, Mac Millan, 2003.
4. R.S.Ambosht, *A Text Book of Plant Ecology*, Students Friends Co., 1990
5. N.B.Subrahmanyam& A.V.S.S. Sambamurty, *Ecology*, Narosa Pub. House, 2000
6. C. Mahoharchary& P.J. Reddy, *Principles of Environmental Studies*, B.S. Pub., 2004.
7. Y.Anjaneyulu, *Introduction to Environmental Science*, B.S.Pub.,2004.
8. R.C.Mohanty, *Environment Change and Management*, Kamal Raj Pub.,New Delhi, 1995.
9. Any text recommended by the Instructor

GENERIC ELECTIVES COURSES-GEC(One Elective paper to be chosen from each group)

GEC-I

1. Combinatorics and Discrete Mathematics — 6 credit

Principles of addition and multiplication, Permutations and Combinations, Counting with the help of mathematical induction, inclusion-exclusion principle and pigeon hole principle. Recurrence relations, counting using recurrence relations, Solving linear homogeneous recurrence relationswith constant coefficients. Stirlings Numbers Generating functions, solving recurrence relations with constant coefficients. Stirlings Numbers Generating

functions, solving recurrences using generating functions, partitions, partiality ordered sets, Lattices, Boolean algebra, Propositional and quantified logic.

Graphs: Basic definitions, complement of graph, clique, independent set, bipartite graph. Graph isomorphisims, subgraph, induced subgraph, path, cycle, walk, Petersen graph, connected component. Degree sum, adjacency matrix and number of walks, shortest path in a weighted graph. Bipartite graphs and odd cycles. Strongly connected component, Eulerian trail in a graph. Edge subdivision, Planarity, K(3,3) and K(5). Kuratowski's theorem (statement only), Euler's theorem, chromatic number, five colour theorem.

Recommended Texts:

1. J.Matousek and J.Nesetril: *Invitation to Discrete Mathematics*, Clarendon press, Oxford.
2. Donald E.Knuth, Ronald L.Graham and O. Patashnik: *Concrete Mathematics*, Pearson Education.
3. C.L.Liu: *Elements of Discrete Mathematics*, Tata McGraw Hill.
4. Frank Harry: *Graph Theory*, Narosa Publishing House.
5. ReinhardDiestel: *Graph Theory*, Springer.
6. Douglas B.West: *Introduction to graph Theory*, Prentice Hall, India.
7. Martin J. Ericson: *Introduction to Combinatorics*, Wiley Interscience.
8. Rosen, *Discrete Mathematics and Its Applications*, Tata McGraw Hill.
9. G.A.Bondy&U.S.R.Murty: *Graph Theory*, Springer.
10. R.A.Brualdi, Introductory Combinatories, Pearson.
11. V. Krishnamurthy; Combinatorics: Theory and Applications.
12. Any text recommended by the Instructor

2. Cryptography — 6 credit

Overview of cryptography, Symmetric and Substitution cipher and their cryptanalysis, Block cipher, Data Encryption Standard (DES), Differential and linear cryptanalysis, Block cipher design principles, block cipher modes of operation, Advanced Encryption Standard (AES).

Principles of Public –key Cryptosystems, The RSA algorithm, key management, Diffie-Hellman Key Exchange, Authentication functions, Message Authentication Codes(MAC), Hash functions.

Discrete Logarithms, ElGamal Cryptosystem, Algorithm for Discrete Logarithm Problem, security of ElGamal System, Schnorr signature scheme, The ElGamal signature scheme, The digital signature algorithm.

Elliptic curve over the reals, Elliptic curves modulo a prime, properties of Elliptic curves point compression and ECIs. Computing point multiples on Elliptic curves, Elliptic curve digitalsignature algorithm, Elliptic curve factorization, Elliptic curve Primality test.

Recommended Texts:

1. W. Stallings-Cryptography and Network Security Principles and Practice, Person Education Asia, 2000.
2. D.Stinson-Cryptography: Theory and Practice, CRC press, 2006.
3. N.Koblitz-A course in Number Theory and Cryptography, Springer verlag.
4. B.Scheier-Applied Cryptography, New York, Wiley, 1996.
5. A.Menezes, P.VanOorsch, S.Vanstans-Handbook of Applied Cryptography, CRC press, 1997.
6. Any text recommended by the Instructor

GEC-II

1. Computer Science-II(Design and Analysis of Algorithms+Lab) 6 credit

Data structures:
Binary trees, binary search trees, heaps, sets and disjoint sets union, graphs (representation, BFS, DFS).

Algorithms:
The role of algorithms in computing, Introduction to design and analysis of algorithms, functions. Asymptotic notations, recurrences.

Divide and conquer: (Heap sort, Quick sort, Lower bounds for sorting, counting sort, FFT, strassen's matrix multiplications). Dynamic programming : (Matrix Chain Multiplication, Floyd warshall algorithm, Longest common subsequence) Greedy method: Fractional knapsack problem, (Huffman codes, Kruskal and Prim's algorithm for finding minimum spanning tree, Dijkstra's algorithm), Backtracking (8-queens problem, sum of subsets), Maxflow, min cuts, Ford Fulkerson method, string matching (Rabin-Karp algorithm), NP-Completeness and approximation algorithms.

Note: Implementation of the algorithms will be done as Lab

Recommended Texts:

1. Dexter Kozen, *Algorithms*, Springer Verlag, 1992.
2. Thomas H. Cormen, Charles E. Leiesersen, Ronald L. Rivest, *Introduction to Algorithms*, MIT press, 2000.
3. Jon Kleinberg and Eva Tardos, *Algorithm Design*, Pearson/ Addison-wesley, 2006.
4. E. Horowitz, S. Sahni, and S. Rajasekharan, *Fundamental of Computer Algorithms*, Galgotia Publications, 2002.
5. A. Aho, J.Hopcroft and J.Ullman: *Data Structures and Algorithms*.
6. T.A. Standish: *Data Structure Techniques*, Addison Wesley.
7. Any text recommended by the Instructor

2. Coding Theory — 6 credit

Basic binary codes, Arithmetic operation modulo a binary polynoid. The number of q-way polynomials of a given degree, The structure of finite fields, Cyclic binary codes, Factorization of polynomials over finite fields, Binary BCH codes for correcting multiple errors nonbinary coding, Enumeration of information symbols-BCH codes, Information rates of optimum codes.

Recommended Texts:

1. E. Berlecamp, *Algebraic Coding*, McGrawHill.
2. Van Lint, *Coding Theory*, Springer.
3. Any text recommended by the Instructor

GEC-III

1. Probability-I — 6 credit

Classical definition of Probability and its limitations, John Venn Frequentist probability, Kolmogorov's Axiomatic approach to define Probability: Conditional probability and Bayes Theorem, Independent of events , Definition of Random variables (discrete and continuous),Distribution and density functions in continuous and discrete cases, Expectation, variance and moment generating function., standard discrete distributions (uniform, Binomial , Poisson, geometric and Hypergeometric), Independence of random variables Univariate densities (normal, exponential, Gamma, Beta, Chi-square and Cauchy) Expectation variance and moments of continuous random variables, Tchebychev's inequality, the weak law of large numbers

Reference Text:

1. K.L. Chung : Elementary probability Theory, Narosa
2. W. Feller: Introduction to Probability Theory and its Applications Vol 1
3. Sheldon Ross: A first cours in Probability
4. V.K. Rohatgi: Introduction to Probability Theory and Mathematical Statistics.

2. Econometrics — 6 credit

Statistical Concepts, Normal distribution; chi-square, t and F-distributions; estimation of parameters; properties of estimators; testing of hypotheses: defining statistical hypotheses; distributions of test statistics; testing hypotheses related to population parameters; Type I and Type II errors; power of a test; tests for comparing parameters from two samples.

Simple Linear Regression Model: Two Variable Case Estimation of model by method of ordinary least squares; properties of estimators; goodness of fit; tests of hypotheses; scaling and units of measurement; confidence intervals; Gauss-Markov theorem; forecasting.

Multiple Linear Regression Model Estimation of parameters; properties of OLS estimators; goodness of fit - R2 and adjusted R2 ; partial regression coefficients; testing hypotheses –

individual and joint; functional forms of regression models; qualitative (dummy) independent variables.

Violations of Classical Assumptions: Consequences, Detection and Remedies Multicollinearity;heteroscedasticity; serial correlation.

Specification Analysis Omission of a relevant variable; inclusion of irrelevant variable; tests of specification errors.

Books Recommended

1. Jay L. Devore, *Probability and Statistics for Engineers*, Cengage Learning, 2010.
2. John E. Freund, *Mathematical Statistics*, Prentice Hall, 1992.
3. Richard J. Larsen and Morris L. Marx, *An Introduction to Mathematical Statistics and its Applications*, Prentice Hall, 2011.
4. D. N. Gujarati and D.C. Porter, *Essentials of Econometrics*, McGraw Hill, 4th Ed., International Edition, 2009.
5. Christopher Dougherty, *Introduction to Econometrics*, Oxford University Press, 3rd Ed., Indian edition,2007.

GEC-IV

1. Computer Sciences-III (CO & OS) — **6 credit**

Computer Organisation:

Introduction to computer architecture, Instruction set, Instruction set principles and trade offs, Computer arithmetic, ALU design, Assessing computer system performance, Amadalie's Law. Pipelining, Pipeline control, pipeline hazards, Basics of caching, Cache mapping, virtual memory, Main memory, Disks and buses, Interfacing Input/ output devices to the memory, processor and operating system.

Operating system:

Process Management (Processes, CPU Scheduling, critical section problem, sunaphora, Dead lock- prevention and avoidance & detection & recovery) storage Management (Memory management- paging & segmentation, virtual memory, file system interface), I/ O system, secondary - storage structure, protection and security. Case study of UNIX/ LINUX system.

Recommended Texts:

1. J. L. Hennessy, and D. A .Patterson, Computer Organization: The Hardware/Software Interface, Morgan Kaufman Publishers 1994.
2. J. L. Hennessy, and D. A .Patterson, Computer Architecture: A Quantitative Approach, Morgan Kaufman Publishers 1990.
3. A. Silberschatz& P. B. Galvin, Operating System concepts, John Wiley.
4. P. C. Bhatt, An Introduction tooperating systems, PHI.
5. Any text recommended by the Instructor.

2. Statistics-I — **6 credit**

Primary and secondary data, Univariate data, Frequency distribution.Diagrammatic representation, Graphical representation and tabulation of data.Measures of central

tendency, dispersion, skewness and kurtosis for data. Moments and quantiles, Correlation and regression, Bivariate frequency distribution.

Basic probability distributions, Binomial, Poisson, normal distributions and their fitting.Negative binomial, exponential and gamma distributions.Joint distribution of independent random variables and their transformations.t, F, and X2- distributions- their derivation and properties.

Recommended Texts:

1. A. M. Gun, M. K. Gupta, and B. Das Gupta: *Fundamentals of Statistics*.
2. A. M. Gun, M. K. Gupta, and B. Dasgupta: *Outline of Statistics*.
3. Any text recommended by the Instructor

GEC-V

1. Computer Science-IV **6 credit**

Overview of database systems, Introduction to database design, The relational model, Relational algebra and calculus, SQL (queries, constrains, Triggers), Overview of storage and indexing, storing data - disks & files, Tree - structured indexing, overview of query evaluation, Evaluating relational operators, A typical relational querry optimizer, schema refinement, functional dependencies, Normal forms, Physical database design and tuning, security and authorization.

Laboratory: SQL

Recommended Texts:

1. R. Ramakrishnan and J. Gehrke - Database Management Systems - MC Grawhill - 3rd Edition 2003.
2. Elmarsi, Navathe: Fundamentals of Database System, Addison Wesley
3. A. Silberschata, H. Korth, S. Sudarshan, Database System Concepts, McGrawhill.
4. Any text recommended by the instructor

2. Topology **6 credit**

Topological spaces, quotient spaces, Separation axioms (Urysohn's lemma, Tietze's extension theorem), Filters and nets, Connectedness and compactness, Covering spaces, fundamental groups.

Recommended Texts:

1. T. James Munkres, Topology, Second Edition, Prentice Hall, 2000.
2. K. J"anich, Topology, Springer, 1984.
3. M. A. Armstrong, Basic Topology., Springer, 1983.

4. G. E. Bredon, Topology and Geometry, Springer GTM 139, 1995.
5. W. S. Massey, A basic coursein algebraic topology, Graduate Texts in Mathematics, 127, Springer-Verlag, 1991.
6. Any text recommended by the Instructor

3. Finite Element Methods — 6 credit

Introduction to finite element methods, comparison with finite difference methods, Methods of weighted residuals, collocations, least squares and Galerkin'smethod.Variational formulation of boundary value problems, equivalence of Galerkin and Ritz methods.
Applications to solving simple problems of ordinary differential equations.
Linear, quadratic and higher order elements in one dimensional and assembly, solution of assembled system.
Simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly, discretization with curved boundaries
Interpolation functions, numerical integration, and modeling considerations.
Solution of two dimensional partial differential equations under different Geometric conditions.

Books Recommended

1. J.N. Reddy, Introduction to the Finite Element Methods, Tata McGraw-Hill, 2003.
2. K.J. Bathe, Finite Element Procedures, Prentice-Hall, 2001.
3. R.D. Cook, D.S. Malkus and M.E. Plesha, Concepts and Applications of Finite Element Analysis,John Wiley and Sons, 2002.
4. Thomas J.R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Dover Publication, 2000.
5.George R. Buchanan, Finite Element Analysis, McGraw Hill, 1994.

4. Algebraic Geometry — 6 credit

Introduction to algebraic geometry- prime ideals and primary decompositions, Ideals in polynomial rings, Hilbert basis theorem, Noether normalization theorem, Hilbert's Nullstellensatz, Projective varieties, Algebraic curves, Bezout's theorem, Elementary dimension theory.

Recommended Texts:

1. M. Reid, Undergraduate Algebraic Geometry, Cambridge.
2. Cox, Little and O'Shea: Ideals, Varieties and Algorithms, Springer.
3. Any text recommended by the Instructor.

GEC-VI

1. Computer Science-V (Theory of Computation) — 6 credit

Regular Languages: Finite automata, Nondeterminism, regular expressions, Non regular Languages.

Context-Free Languages: Context free grammars, Push down automata, Non-context-free languages.

The church Turing Thesis: Turing machines, Variants of Turing machines, the definition of algorithm.

Decidability: Decidable languages, The Halting problem.

Reducibility: Undecidable problems from language theory, Mapping reducibility.

Complexity Theory: Measuring complexity, The P and NP completeness.

Recommended Texts:

1. M.Sipser-*Introductionto thetheoryofcomputation*-ThomsonLearning-2001, Chapter:1,2,3,4,5,7.
2. J.E.Hopcroft,Motwani,J.D.Ullman-*IntroductiontoAutomataTheory,LanguagesandComputation*,2ndEdition,Pears onEducation,2001.
3. AnytextrecommendedbytheInstructor.

2. Statistics-II — 6 credit

Parametric families.Sample space.Parameterspace.Pointestimation.Criteria of good estimators.Consistency, bias, efficiency, sufficiency.Rao.Cramer inequality.UMVU estimation. Complete Sufficiency. Maximum likelihood estimation, Interval estimation.Testing of hypothesis.Simple and composite hypothesis.Neyman-Pearson's theory.Most powerful.UMP and UMPU tests.

Likelihood ratio and related tests.Large sample tests.Large sample tests.Elements of Bayesian inference.

Recommended Texts:

1. Gun, A.M., Gupta, M.K. and Das Gupta, B. An outline of Statistics. Vol-II
2. Rohatgi, G.K-Probability and Mathematical Statistics
3. Rao, C.R.-Linear Statistical Inference.
4. Any text recommended by the Instructor

3. Functional Analysis — 6 credit

Normed linear spaces and continuous linear transformations, Hahn-Banach theorem (analytic and geometric versions), Baire's theorem and its consequence - three basic principles of functional analysis (open mapping theorem, closed graph theorem and uniform boundedness principle), Hilbert spaces - Riesz representation theorem, adjoint operator, etc., Compact operators, Spectral theorem for self adjoint compact operators.

RecommendedTexts:

1. W. Rudin, Functional analysis, McGraw-Hill, Inc., 1991.
2. J. B. Conway, A course in functional analysis, Graduate Texts in Mathematics, 96., Springer-
   Verlag, 1990.
3. K. Yosida, Functional analysis, Grundlehren der MathematischenWissenschaften, 123., Springer-Verlag, 1980.
4. Any text recommended by the Instructor

4. Lie Algebras and Group Representations — 6 credit

Matrix Lie group:

Definitions, examples, compactness, connectedness, simple connectedness, homomorphisms and isomorphisms. Definition of Lie group, examples..... Introduction to Lie Algebras and exponential Maplings and basic properties.The matrix exponetial the matrix logarithm, Lie algebra of a matrix,Lie group and the exponential mapping.The Baker-Campbell-Hausdroff Formula.

Basis representation Theory starting with finite groups. Examples of representation.Operations on representations. Direct sums the tensor product and related topics. Irreducible representations of complete reducibility.Schur lemma.Group versus Lie algebra representation.Covering groups.

Recommended Texts:

1. Brain C. Hall, Lie groups, Lie Algebras and representations, Springer
2. Alexander Kirillv Jr. Introduction to Lie group and Lie algebras available online
3. Jean-Pierre Serre. Linear representations of finite groups, Springer
4. William Fulton and Joe Harris, Representation theory: A first course, Springer
5. Any text recommended by the Instructor

GEC-VII

1. Mechanics — 6 credit

Unit-I

Lagrangian Dynamics:
Basic concepts, coordinate system, degrees of freedom for N- particle system, constraints, force of constraints, generalised coordinates, virtual displacement and principle of virtual work, D' Alembert's Principle, Derivation of Lagrange equation of motion from D' Alembert's principle, Hamilton's principle and La- grange equation of motion. Symmetry properties (invariance Principle) of space and time and conservation Laws, (4 classes)

Hamiltonian Dynamics:
Generalised momentum and cyclic coordinates, conservation of linear and angular momentum, Hamilton's function and conservation of energy, Hamilton's equations of motion in different coordinate systems and application to Harmonic Oscillator and compound pendulum. (4 classes)

Unit-II

Central force problem:
Reduction of two-body central force problem to equivalent one-body problem, central force and motion in a plane, Equation of motion under central force and first integral, differential equation of the orbits, Inverse square law of force, Kepler's laws(three) of planetary motion and their deductions, Artificial satellite, Virial theorem. (8 classes)

Unit-III

Variational Principle:
Calculus of variation and Euler-Lagrange equation of motion, deduction of Hamilton's principle from D' Alembert's principle.Lagrange equation of motion for nonholonomic system (method of undetermined multiplier), Δ-variation and principle of least action. (4 classes)

Canonical Transformation:
Legendre transformation, generating function and its significance, Procedure for application of canonical transformation, conditions of canonical transformation, application Harmonic Oscillator problem, Integral invariance of Poincare, infinitesimal contact transformation and conservation theorems. (4 classes)

Unit-IV
Poisson's and Lagrange brackets, their relation, Fundamental Poisson's brackets, invariance of Poisson's bracket under canonical transformation, phase space and Liouville's theorem.

Hamilton-Jacobi(H-J) theory:
Derivation of H-J equation, Hamiltons principal and characteristic functions, application to Simple Harmonic oscillator, Kepler's problem

Action-angle variable:
Theory of action angle variable, general case, deduction of frequency, application to Simple Harmonic Oscillator, Kepler's problem. (8 classes)

Unit-V

Small Oscillation:
Theory of small oscillation, normal coordinates and normal frequency, application to triatomic molecule, (3 classes)

Rigid-body dynamics:

Rigid body, generalised coordinates for its dynamics, Body and space set of axes, Euler's angle, infinitesimal rotation as vector-angular velocity, angular momentum and inertia tensor, Principal axes and principal moments of inertia of a rigid body, rotational kinetic energy, torque free motion (5 classes)

Motion of Spherical Symmetric Field:

Hydrogen atom, reduction to equivalentone body problem, radial equation, energy eigenvalues and eigenfunctions, degeneracy, radial probability distribution.

Free particle problem incoming and outgoing spherical waves, expansion of plane-waves in terms of spherical waves, bound states of a 3-D square well, particle in a sphere.

RecommendedTexts:

1.L-ISchiff,J.Sakurai,E.Merzbacher,A.Messiash,*QuantumMechanics*,Vol.1.

2.S.Gasiorowicz, *QuantumPhysics*.

3.P.Roman,*AdvancedQuantumMechanics*.

4.M.E.Rose, *ElementaryTheoryofAngularMomentum*.

2. Quantum Mechanics — 6 credit

General Principles of Quantum Mechanics:

Linear vector space, ket and bra vectors, scalar product of vectors and their properties, linear operators, adjoint operators, unitary operators, expectation values of dynamical variables and physical interpretation, Hermitian operators, eigenvalues and eigenvectors, orthogonality of eigenvectors, probability interpretation, degeneracy, Schmidt method of orthogonalization.

Expansion theorem, completeness and closure property of the basis set, coordinate, momentum and energy representations.

Compatible and incompatible observables, commutator algebra, uncertainty relation as a consequence of noncommutability, minimum uncertainty, wavepacket. Representation of ket and bra vectors,abd operators in the matrix form, unitary transformation of basis vectors and operators.

Quantum Dynamics:

Time evolution of quantum states, time evolution operator and its properties, Schrodinger picture, Heisenberg picture, Interaction picture, equations of motion, operator method solution of harmonic oscillator, matrix representation and time evolution of creation and annihilation operators, density matrix.

Rotation and Orbital Angular Momentum:

Rotation matrix, angular momentum operators as generators of rotation, Lx, Ly, Lz and L 2 and their commutator relations, raising and lowering operators, Lx, Ly, Lz and L 2 in spherical polar coordinates, eigenvalues and eigenfunctions of Lz, L 2 (OP method), spherical harmonics, matrix representation of L+, L- and L 2.

Spin ½ particles, Pauli spin matrices and their properties eigenvalues and eigenfunctions, spinor transformation under rotation.
Total angular momentum J, eigenvalue problem of Jz and J2, angular momentum matrices, addition of angular momenta and C. G. coefficients, angular momentum states for composite systems in the angular momenta (1/ 2, 1/ 2) and (1, 1/ 2).

Motion of Spherical Symmetric Field:
Hydrogen atom, reduction to equivalentone body problem, radial equation, energy eigenvalues and eigenfunctions, degeneracy, radial probability distribution.
Free particle problem incoming and outgoing spherical waves, expansion of plane-waves in terms of spherical waves, bound states of a 3-D square well, particle in a sphere.

Recommended Texts:
1. L-I Schiff, J. Sakurai, E. Merzbacher, A. Messiash,*Quantum Mechanics*, Vol. 1.
2. S. Gasiorowicz, *Quantum Physics*.
3. P. Roman,*Advanced Quantum Mechanics*.
4. M. E. Rose, *Elementary Theory of Angular Momentum*.
5. Any text recommended by the Instructor.

3. Electrodynamics — 6 credit

Maxwell's Equations:

Green's function, solution of Maxwell's equation, Lorentz and Coulomb Gauge, Gauge invariance, plane waves in a non-conducting medium, linear and circular polarizations, Stoke's parameters, frequency dispersion characteristics or dielectrics, conductors and plasma. Waves in a dispersive medium, Kramer-Kroning relations.

Cylindrical cavities and wave-guides, mode in a rectangular wave guide, resonant cavities.

Radiation, Scattering and Diffraction:

Fields and radiation of a localized oscillating source, electricdipole, magnetic dipole and electric quadruple fields radiation, centrefed linear antenna with sinusoidalcurrent, scattering by a small dielectric sphere in long wavelength limit, Rayleigh scattering, Kirchoffs formulation of diffraction by a circular aperture.

Covariant formulation:

Four vector notation, Relativistics particle kinematics and dynamics, Covariant form of Maxwell's equations, Maxwell field tensor, transformation of electromagnetic field components, Lagrangian of a charged particle in an external EM field and EL equations.

Radiation By Moving Charges:

Lienard-Wiechert potential and field for a point charge, total power radiated by an accelerated charge, larmors formula, angular distribution of radiation from an accelerated charge, Thompson scattering.

Recommended Texts:

1. J. D. Jacksons,*Classical Electrodynamics.*
2. A. Z. Capri and P. V. Panant, *Introduction to Electrodynamics.*
3. M. Born and E. Wolf, *Principles of Optics.*
4. Any text recommended by the Instructor.

4. Relativity and Gravitation **6 credit**

Review of special relativity, manifolds and tensor fields, curvature, Einstein's equation, homogeneous and isotropic cosmology, the Schwarzchild solution black holes.

Recommended Texts:

1. R. M. Wold, General Relativity, University of Chicago Press.
2. S. Chandrasekhar, Mathematical Theory of Black Holes, Oxford University Press.
3. Einstein et al, Principles of Relativity, Dover.
4. P. G. Bergman, Introduction to Theory of Relativity
5. Weimberg, Gravitation and Cosmology, Wiley.
6. Any text recommended by the Instructor

DISCIPLINE SPECIFIC ELECTIVE COURSE-DSE (One Elective paper to be chosen from each group)

DSE-I

1. Applications of Algebra **6 credit**

Balanced incomplete block designs (BIBD): definitions and results, incidence matrix of a BIBD, construction of BIBD from difference sets, construction of BIBD using quadratic residues, difference set families, construction of BIBD from finite fields.

Coding Theory: introduction to error correcting codes, linear cods, generator and parity check matrices, minimum distance, Hamming Codes, decoding and cyclic codes.

Symmetry groups and color patterns: review of permutation groups, groups of symmetry and action of a group on a set; colouring and colouring patterns, Polya theorem and pattern inventory, generating functions for non-isomorphic graphs.

Special types of matrices: idempotent, nilpotent, involution, and projection tri diagonal matrices, circulant matrices, Vandermonde matrices, Hadamard matrices, permutation

and doubly stochastic matrices, Frobenius- König theorem, Birkhoff theorem. Positive Semi-definite matrices: positive semi-definite matrices, square root of apositive semi-definite matrix, a pair of positive semi-definite matrices, and their simultaneous diagonalization. Symmetric matrices and quadratic forms: diagonalization of symmetric matrices, quadratic forms, constrained optimization, singular value decomposition, and applications to image processing and statistics.

Applications of linear transformations: Fibonacci numbers, incidence models, and differential equations. Least squares methods: Approximate solutions of system of linear equations, approximate inverse of an m×n matrix, solving a matrix equation using its normal equation, finding functions that approximate data. Linear algorithms: LDU factorization, the row reduction algorithm and its inverse, backward and forward substitution, approximate inverse and projectionalgorithms.

Books Recommended :

1. I. N. Herstein and D. J. Winter, Primer on Linear Algebra, Macmillan Publishing Company, New York, 1990.
2. S. R. Nagpaul and S. K. Jain, Topics in Applied Abstract Algebra, Thomson Brooks and Cole, Belmont, 2005.
3. Richard E. Klima, Neil Sigmon, Ernest Stitzinger, Applications of Abstract Algebra with Maple, CRC Press LLC, Boca Raton, 2000.
4. David C. Lay, Linear Algebra and its Applications. 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.

2. Portfolio Optimization — 6 credit

Financial markets.Investmentobjectives.Measures of return and risk.Types of risks.Risk free assets.Mutualfunds.Portfolio of assets.Expected risk and return of portfolio.Diversification.

Mean-variance portfolio optimization- the Markowitz model and the two-fund theorem, risk-free assets and one fund theorem, efficient frontier. Portfolios with short sales. Capital market theory.

Capital assets pricing model- the capital market line, beta of an asset, beta of a portfolio, security market line. Index tracking optimization models.Portfolio performance evaluation measures.

Books Recommended

1. F. K. Reilly, Keith C. Brown, *Investment Analysis and Portfolio Management*, 10th Ed., South-Western Publishers, 2011.
2. H.M. Markowitz, *Mean-Variance Analysis in Portfolio Choice and Capital Markets*, Blackwell, New York, 1987.
3. M.J. Best, *Portfolio Optimization*, Chapman and Hall, CRC Press, 2010.
4. D.G. Luenberger, *Investment Science*, 2nd Ed., Oxford University Press, 2013.

3. Classical Geometry — 6 credit

Euclid's Geometry: Introduction, Ruler and compass constructions, Euclid's Axiomatic Method, Construction of the regular pentagon.

Hilbert's axioms for geometry: Axioms of Incidence, Betweenness, Congruence for line segments, Congruence for angles, Hilbert Planes, Intersection of Lines and Circles, Euclidean planes. Geometry over fields: The real Cartesian plane, Abstract fields and incidence, Ordered fields and betweenness, Congruences of segments and angles, Rigid motions and SAS.

Segment Arithmetic: Addition and multiplication of line segments, Similar triangles, Introduction to coordinates.

Introduction to conics and conicoids.

Discussion and history of the parallel postulate.

Books Recommended

1. R. Hartshorne: *Geometry, Euclid and Beyond*, Springer, UTM.

2. R. J. T. Bell, *Coordinate Geometry of Three Dimensions*, Macmillan and Co.

3. R. Bix: Conics and Cubics: *A concreteintroduction to algebraic curves*, Springer UTM.

4. H. S. M. Coxeter and S. L. Greitzer: *Geometry Revisited,* Random House, New York, 1967/ Dover.

5. K. Kendig, *Conics*, Dolciani Mathematical Exposition no. 29, Mathematical Association of America.

6. Any text recommended by the Instructor

4. Theory of Equations — 6 credit

General properties of polynomials, Graphical representation of a polynomial, maximum and minimum values of a polynomials, General properties of equations, Descarte's rule of signs positive and negative rule, Relation between the roots and the coefficients of equations.Symmetric functions, Applications of symmetric function of the roots, Transformation of equations. Solutions of reciprocal and binomial equations.Algebraic solutions of the cubic and biquadratic.Properties of the derived functions.

Symmetric functions of the roots, Newton's theorem on the sums of powers of roots, homogeneous products, limits of the roots of equations.

Separation of the roots of equations, Strums theorem, Applications of Strum's theorem, Conditions for reality of the roots of an equation and biquadratic. Solution of numerical equations.

Books Recommended:

1. W.S. Burnside and A.W. Panton, The Theory of Equations, Dublin University Press, 1954.
2. C. C. MacDuffee, Theory of Equations, John Wiley & Sons Inc., 1954.

DSE-II

1. Optimization and LPP — **6 credit**

Elementary Optimization, Univariate and multivariate optimization, constrained optimization. Linear programming: motivation and brief history, its formulation including examples from real life problems, graphical solution of LPP of two variables.

Basic concepts of linear programming, like, basic feasible solutions, extreme points andbasic feasible solutions relationship, standard form of LPP, Simplex method, examples, artificial variables, two phase method, examples should include depiction of infeasibility, unboundedness, and alternate optimal solutions.

Duality theory for LPP, motivation to study duality in LPP, duality theorems and their economic interpretations, examples, complementarity slackness theorem, finding solution of one problem from another.

Applications of linear programming framework: transportation and assignment problems, North West corner rule, Vogel's method, Hungarian method, examples, role of duality theory in attaining optimal solutions for both TP and AP problems.

Unconstrained scalar differentiable nonlinear programming problems in space Rn, steepest descent direction method, illustrations, and numerical difficulties associated with this technique, convergence analysis for example convex quadratic optimization problems. Introduction to nonlinear programming, concept of feasible solution, Karush-Kuhn Tucker conditions, constraint qualifications, highlight the role of convexity.

Numerical implementation of simplex method and steepest descent method.

Recommended Texts:

1. D. G. Luenberger, *Linear and Nonlinear programming*, 3rd ed, Springer 2008.
2. O. H. Taha, *Operations Research*, 8th ed, Prentice Hall, 2002.
3. K. Lange, *Optimization*, Springer Verlag, 2004.
4. S. Chandra, Jayadeva, A. Mehra, *Numerical Optimization with Applications*, Narosa, 2009.

5. R. J. Venderbei,*Linear programming: Foundation and extensions*, 2nd ed, Springer, 2001.
6. G. Hadley, *Linear programming*, Narosa, 2002.
7. Any text recommended by the Instructor

2. Industrial Mathematics — 6 credit

Medical Imaging and Inverse Problems. The content is based on Mathematics of X-ray and CT scan based on the knowledge of calculus, elementary differential equations, complex numbers and matrices.

Introduction to Inverse problems: Why should we teach Inverse Problems? Illustration of Inverse problems through problems taught in Pre-Calculus, Calculus, Matrices and differential equations. Geological anomalies in Earth's interior from measurements at its surface (Inverse problems for Natural disaster) and Tomography.

X-ray: Introduction, X-ray behavior and Beers Law (The fundament question of image construction) Lines in the place.

Radon Transform: Definition and Examples, Linearity, Phantom (Shepp - Logan Phantom - Mathematical phantoms).

Back Projection: Definition, properties and examples.

CT Scan: Revision of properties of Fourier and inverse Fourier transforms and applications of their properties in image reconstruction. Algorithms of CT scan machine. Algebraic reconstruction techniques abbreviated as ART with application to CT scan.

Books Recommended:

1.Timothy G. Feeman, The Mathematics of Medical Imaging, A Beginners Guide, Springer Under graduate Text in Mathematics and Technology, Springer, 2010.

2. C.W. Groetsch, Inverse Problems, Activities for Undergraduates, The Mathematical Association of America, 1999.

3. Andreas Kirsch, An Introduction to the Mathematical Theory of Inverse Problems, 2nd Ed., Springer,2011.

3. Soft Computing Methods — 6 credit

Unit-1. Neural Network topologies, activation functions and learning methods, perception training algorithm, The multilayer perception (MLP), Back Propagation learning algorithm, financial applications.

Unit-2. Self organization maps, Support vector machine for classification and regression, application to finance.

Unit-3.Genetic algorithm (GA), MLP-GA, SVM-GA hybrid methods and financial applications.

Unit-4. Elements of fuzzy set theory, Fuzzy logic and approximate reasoning, Neurofuzzy and Fuzzy –GA hybrid methods, Rough set theory financial applications.

Unit-5. The particle swarm optimization algorithm, Discrete PSO, MLP-Swarm Hybrids, Ant colony optimization methods, financial applications.

Books Recommended:

1. S.Haykin-Neural Networks: a comprehensive foundation, Pearson Education, 2001

2. Brabazan, M.O' Neill-Biologically Inspired Algorithm for Financial ModellingSpringer-2006

3. R.A. Aliev, B.Fazlollahi, R.R. Aliev-Soft Computing and its Applications in Bussines and Economic, Springer Verlag, 2004.

4. Relevant research papers an use of soft computing methods for financial problems.

4. Artificial Intelligence — 6 credit

Artificial Intelligence: Introduction, Intelligent Agents: Agents & Environments, Concept of Rationality, Nature & Structure of Agents; Problem Solving: Solving Problems by Searching, Classical Search, Adversarial Search, Constraint Satisfaction Problems. Knowledge, Reasoning and planning: Logical agents, First order logic, Inference in First order logic.

Classical planning, Knowledge Representation: Uncertain Knowledge and Reasoning: Probabilistic Reasoning, Learning from Examples, Knowledge in learning; Natural Language Processing: Language models, Text Classification, information retrieval, information extraction.

Natural Language for Communication: Phrase structure Grammars, Syntactic Analysis, Augmented grammars and semantic interpretation, Machine translation, Speech recognition; Perception; Expert Systems: Introduction, Design of Expert systems.

Recommended Texts:

1. Stuart Russell and Peter Norving, "Artificial Intelligence: A Modern Approach", Third Edition, 2010, Pearson Education, New Delhi.
   Chapters: 1,2,3,4 (4.1,4.2), 5 (5.1, 5.2,5.3), 6,7,8,9,10 (10.1, 10.2, 10.3, 10.5), 12,14 (14.1-14.6), 18(18.1-18.7), 19(19.1,19.2,19.3), 22,23,24(24.1-24.3,24.5).
2. Joseph Giarratano and Gary Riley,"*Expert Systems: Principles and Programming*", Fourth Edition, CENGAGE Learning India Pvt. Ltd., New Delhi.

3. Elanie A. Rich and Kevin Knight, *"Artificial Intelligence"*, 3rd Edition, 2009, McGraw-Hill Education (India), New Delhi.
4. Nills J. Nilsson, *"Artificial Intelligence: A New Synthesis"* 2nd Edition, 2000,Elsiver India Publications, New Delhi.
5. Michael Negnevitsky, *"Artificial Intelligence: A Guide to Intelligent Systems"*, Second Edition, 2005, Pearson Education, Inc. New Delhi.
6. Dan W. Patterson, *"Introduction to Artificial Intelligence and Expert Systems"*,1st Edition, 1996, PHI Learning Pvt. Ltd., New Delhi.
7. Ben Coppin, *"Artificial Intelligence Illuminated"*, 2005, Narosa Publication, New Delhi. ISBN: 978-81-7319-671-3.
8. Any text recommended by the Instructor

5. Discrete Dynamical System — 6 credit

Unit-I: Representations of Dynamical Systems, Dynamical systems with discrete time. Types of trajectories, fixed and periodic points, Attracting, repelling and saddle fixed and periodic points and Chaos, Lyapunov Exponent.

Logistic Map, Hennon Map, Lorenz Model, Rossler Map, Horseshoe map, Complex Quadratic Map, Tent Map, Duffing Map.

Unit-II: Fractals: Cantor Set, Sierpinski Triangle, Koch Curve, Fractal dimension, Similarity Dimension, Box-counting dimension.

Unit-III: Cellular Automata: Components of Cellular Automata, Basic types, Space time diagram and state transition diagram of CA rules, Rule Space, Boolean functions, Matrix and Polynomial representation of Cellular Automata rules, Classification of Cellular Automata rules, Density Classification Task, Relation of Cellular Automata with other areas.

Unit-IV: L-System, Tilings, Iterated Function System, Mathematical Morphological Operations: Erosion, Delition, Opening and Closing and Integral Value Transformations.

Unit-V: Pattern Formation, Pattern Recognition, Pattern Classification and Pattern Analysis, & Applications.

Lab work

Implementation of following methods using R or Python or Matlab:

1. Program for Fractal formation and calculating its fractal dimension.

2. Program for obtaining the space time diagram and STD for CA rules.

3. Program for finding patterns for different IVTs.

4. Any other program recommended by the instructor.

Recommended Text

1. Barnsley, Michael F.; and Rising, Hawley; Fractals Everywhere. Boston: Academic Press Professional, 1993. ISBN 0-12-079061-0
2. Mandelbrot, Benoit B.; The Fractal Geometry of Nature. New York: W. H. Freeman and Co., 1982. ISBN 0-7167-1186-9
3. S. Wolfram, A New kind of Science, Wolfram Publisher, 2002.
4. GrzegorzRozenberg and ArtoSalomaa. The mathematical theory of L systems (Academic Press, New York, 1980). ISBN 0-12-597140-0.
5. GrzegorzRozenberg, ArtoSalomaa – Lindenmayer Systems: Impacts on Theoretical Computer Science, Computer Graphics, and Developmental Biology ISBN 978-3-540-55320-5
6. Mathematical morphology: from theory to applications, Laurent Najman and Hugues Talbot (Eds). ISTE-Wiley. ISBN 978-1-84821-215-2. (520 pp.) June 2010.
7. Image Analysis and Mathematical Morphology, Volume 2: Theoretical Advances by Jean Serra, ISBN 0-12-637241-1 (1988)
8. Discrete Dynamical Systems, OdedGalor, Springer.
9. *Nonlinear Dynamics and Chaos with Applications to Physics, Biology, Chemistry and Engineering* by Steven H. Strogatz, published by Addison Wesley (1994).
10. Any Text Recommended by the Instructor.

DSE-III

1. Computer Science-VI(Computer Network) — **6 credit**

Introduction, Network models, Physical layer (Signals, digital and analog transmission, Multiplexing, circuit switching), Data Link Layer (Error detection and correction, Data link control and Protocols, PPP, Local area networks, connecting LANS, Cellular telephone and satellite network), Network Layer (Host-to-host delivery - inter networking, addressing, and routing), Network layer protocols), Transport Layer (Process to process Delivery : VDP and TCP, Congestions control and quality of service), Application Layer (Client server models, Domain name system, SMTP, FTP, HTTP and WWW), Security (Cryptography, Manage security, user authentication and key management)

Recommended Texts:

1. B.A.Forouzan-*DataCommunicationsandNetworking*,TMH,3rdEdition,2004.
2. A.S.Tanenbaum,*ComputerNetworks*,PrenticeHall
3. W.Stallings,*ComputerNetworkingwithInternetProtocolsandTechnology*PrenticeHall
4. Any text recommended by the Instructor

2. Probability-II — **6 credit**

Joint and Conditional distributions (discrete and continuous) , Distribution of Sums of independent identical distributions, Conditional Expectation, Characteristics function and its properties, Inversion Theorem, Continuity Theorem for characteristic functions (without

proof) and its applications, Central limit Theorem for i.i.d. case with finite variance, Elements of modes of convergence of random variables and their interrelationship (with proof or examples). The strong Law of Large Numbers for i.i.d. random variables.

Reference Text:

1. K.L. Chung : Elementary probability Theory
2. W. Feller: Introduction to Probability Theory and its Applications Vol I and vol II
3. V.K.Rohatgi: Introduction to Probability Theory and Mathematical Statistics.
4. Patrick Billingseley: Probability and Measures

3. Number Theory-II — 6 credit

Introduction to Projective Geometry. The Group law on a cubic. Weierstrass normal form of a cubic.Explicit formula for the group laws.Points of finite order. The Nagell-Lutz Theorem;.Calculating the points of finite order on a curve.Heights of points on an elliptic curve.Mordell'sTheorem.Calculating the rank of some curves.Points over finite fields.

Recommended Texts:

J H Silverman and J Tate, Rational points on Elliptic Curves, Springer Undergraduate Textsin Mathematics Springer-Verlag, 1992.

References:

1. J.W.S. Cassels, Lectures on Elliptic Curves, LMS Student Texts 24 (Cambridge University Press, 1991).
2. N. Koblitz, Introduction to Elliptic Curves and Modular Forms, Graduate Texts in Mathematics 97, Springer-Verlag, 1993.
3. J. H. Silverman, The Arithmetic of Elliptic Curves, Graduate Texts in Mathematics 106, Springer, 2009.
4. A. W. Knapp, Elliptic Curves, Mathematical Notes 40, Princeton University Press, 1992.

4. Bio-Mathematics/Bio Informatics — 6 credit

Molecular Biology Primer. Restriction mapping algorithm, Motif finding problem, Algorithms for motif finding (brute force, branch-and-bound and greedy) Edit distance and alignment, Global and local sequence alignment, multiple sequence alignment, Gene Prediction.

DNA sequencing, shortest superstring problem, sequencing by hybridization (SBH), SBH as Hamiltonian and Eulerian path problem, Fragment Assembly problem.

Distance and character based methods for phylogenetics.

Recommended Texts:

1. N. C. Jones and P. A. Bavzner, An introduction to Bioinformatic algorithms, MIJ Press,2004.

Relevant parts of chapters 2,4,5,6,8 and 10.

2. Dan E Krane, M. L. Baymer, Fundamental concepts of Bioinformatics, Pearson Education, 2003.
3. D. Gusfied, Algorithms on strings, Tress and sequences, Computer Science and computational Biology, Cambridge University Press, 1997.
4. M. S. Waterman, Introduction to computational Biology, Chapman Hall, 19995.
5. Any text recommended by the Instructor

5. Data Analytics — 6 credit

(I) Predictive Analytics

1. **Linear Methods for Regression and Classification:** Overview of supervised learning, Linear regression models and least squares, Multiple regression, Multiple outputs, Subset selection, Ridge regression, Lasso regression, Linear Discriminant Analysis, Logistic regression, Principal Component Analysis.

2. **Model Assesment and Selection:** Bias, Variance, and model complexity, Bias-variance trade off, Estimate of In-sample prediction error, Effective number of parameters, Bayesian approach and BIC, Cross- validation, Boot strap methods, conditional or expected test error.

3. **Additive Models, Trees, and Boosting:** Generalized additive models, Regression and classification trees, Boosting methods-exponential loss and AdaBoost, Random forests and analysis.

4. **Neural Networks(NN), Support Vector Machines(SVM), and K-nearest Neighbor:** Fitting neural networks, Back propagation, Issues in training NN, SVM for classification, Reproducing Kernels, SVM for regression, K-nearest –Neighbour classifiers, clustering and K-means.

(II) Inferential Statistics and Prescriptive analytics

5. Assessing Performance of a classification Algorithm(t-test, McNemar's test, Paired ttest, paired F-test), Analysis of Variance.

(III) Lab work

6. **Implementation of following methods using R or Python or Matlab:**

Simple and multiple linear regression, Logistic regression, Linear discriminate analysis, Ridge regression, Cross-validation and boot strap, Fitting classification and regression trees, K-nearest neighbours, Principal component analysis, K-means clustering.

Recommended Texts:

1.Trevor Hastie, Robert Tibshirani, Jerome Friedman , The Elements of Statistical Learning-Data Mining, Inference, and Prediction, Second Edition , Springer Verlag, 2009.

2. G. James, D. Witten, T. Hastie, R. Tibshirani-An introduction to statistical learning with applications in R,Springer,2013.

3. E. Alpaydin, Introduction to Machine Learning, Prentice Hall Of India, 2010.

References:

1. C. M. Bishop –Pattern Recognition and Machine Learning, Springer, 2006 2. L. Wasserman-All of statistics Texts 1 and 2 and reference 2 are available on line.
2. Any text recommended by the instructor.

DES-IV

1. Project Work — 6 credit

SKILL ENHANCEMENT COURSE-SE (One Elective paper to be chosen from each group)

SE-I

1. Object Oriented Software Engineering — 2 credit

Unit-1. Introduction, Software life cycle modules, Requirements Analysis and specification, software
design, Function oriented software design.

Unit-2. Coding and Testing, Software reliability and quality management, Computer Aided Software Engineering, Software maintenance.

Unit-3. Introduction to object oriented Analysis and Design, Iterative Development and the unified process, case study-The next-Gen POS, Inception, Understanding Requirements, Use case Model, Indentifying other requirements.

Unit-4. Elaboration, Use case Model, Drawing system sequence diagrams, Visualizing concepts, Adding Associations, Adding attributes, Adding details with operation contracts, Interaction diagram notation.

Unit-5. PATTERNS, GRASP, Creating design class diagrams, GOF Design pattern Planning and project queues comments on iterative development and the UP, Rational Unified Process.

Text Book:

1. Crag Larman: Applying UML and Patterns-An introduction OOAP & D and the Unified process, Pearson Education Asia.

2. Rajib Mail: Fundamentals of software Engineering, PHI.

2. Transportation and Game Theory — 2 credit

Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.

Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure.

Books Recommended

1. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004.
2. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore, 2009.

3. Modelling and Simulation — 2 credit

Systems and environment: Concept of model and model building, model classification and representation, Use of simulation as a tool, steps in simulation study.

Continuous-time and Discrete-time systems: Laplace transform, transfer functions, state space models, order of systems, z-transform, feedback systems, stability, observability, controllability. Statistical Models in Simulation: Common discrete and continuous distributions, Poisson process, empirical distributions.

Random Numbers: Properties of random numbers, generation of pseudo random numbers, techniques of random number generation, tests for randomness, random variate generation using inverse transformation, direct transformation, convolution method, acceptance-rejection.

Books Recommended

1. NarsinghDeo, System Simulation with Digital Computer, Prentice Hall of India, 1999.
2. Averill Law, Simulation Modeling and Analysis, 3rd Ed., Tata McGraw-Hill, 2007.
3. G. Gordan, System Simulation, 2nd Ed., Pearson Education, 2007.
4. A.F. Seila, V. Ceric and P. Tadikamalla, Applied Simulation Modeling (International Student Edition), Thomson Learning, 2004.
5. Jerry Banks, Handbook of Simulation: Principles, Methodology, Advances, Applications and Practice, Wiley Inter Science, 1998.
6. J. Banks, J.S. Carson, B.L. Nelson, Discrete Event System Simulation, 4th Ed., Prentice Hall of India, 2004.
7. N.A. Kheir, Systems Modeling and Computer Simulation, Marcel Dekker, 1988.
8. B.P. Zeigler, T.G. Kim, and H. Praehofer, Theory of Modeling and Simulation, 2nd Ed., Academic Press, 2000.

4. Internet of Things — 2 credit

Introduction to IoT: Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications, Interoperability in

IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry Pi, Implementation of IoT with Raspberry Pi, Introduction to SDN, SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud, Fog Computing, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT, Case Study: Agriculture, Healthcare, Activity Monitoring.

Books Recommended:

1. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press)
2. "Internet of Things: A Hands-on Approach", by ArshdeepBahga and Vijay Madisetti (Universities Press)
3. Any text recommended by the instructor.

5. Parallel Computing — 2 credit

1. Introduction to Parallel Computing –
   Motivation and scope. Parallel computing platforms, physical organization of parallel computing platforms. Communication costs in parallel machines.
2. Principles of Parallel Algorithm Design- (Decomposion, Tasks and interactions, mapping techniques for load balancing, methods of containing interaction overheads, parallel algorithm model), Basic communication operations.
3. Analytical modeling of parallel programs- (Sources of overhead, performance metrics, scalability, asymptotic analysis of parallel programs). Sorting on parallel computers (Sorting Networks, Quick sort)
4. Dense Matrix Algorithms- Matrix-Vector multiplication, Matrix-Matrix multiplication, solving system of linear equation-direct and interactive methods.

Text Book Recommended

A.Grma, A. Gupta, G. Karypis, V. Kumar. Introduction to Parallel Computing, Pearson Education, Indian reprint, 2005

SE-II

1. Computer Graphics — 2 credit

Development of computer Graphics: Raster Scan and Random Scan graphics storages, displays processors and character generators, colour display techniques, interactive input/output devices. Points, lines and curves: Scan conversion, line-drawing algorithms, circle and ellipse generation, conic-section generation, polygon filling anti aliasing. Two-dimensional viewing: Coordinate systems, linear transformations, line and polygon clipping algorithms.

Books Recommended:

1. D. Hearn and M.P. Baker, Computer Graphics, 2nd Ed., Prentice–Hall of India, 2004.
2. J.D. Foley, A van Dam, S.K. Feiner and J.F. Hughes, Computer Graphics: PrinciplesandPractices, 2nd Ed., Addison-Wesley, MA, 1990.
3. D.F. Rogers, Procedural Elements in Computer Graphics, 2nd Ed., McGraw Hill BookCompany, 2001.
4. D.F. Rogers and A.J.Admas, Mathematical Elements in Computer Graphics, 2nd Ed., McGraw Hill Book Company, 1990.

2. Logic and Set Theory — 2 credit

Propositional Logic:

Propositions and connectives, syntax; Semantics - truth assignments and truth tables, validity and satisfiability, tautology; Adequate set of connectives; Equivalence and normal forms; Compactness and resolution; Formal reducibility - natural deduction system and axiom system; Soundness andcompleteness.

Predicate Logic:

Syntax of first order language; Semantics - structures and interpretation; Formal deductibility; First order theory, models of a first order theory (definition only), validity, soundness, completeness, compactness (statement only), outline of resolution principle.

Introduction to Computability

Recommended Texts:

1. E. Mendelsohn: Introduction to Mathematical Logic, 2nd Ed. Van-Nostrand, London, 1979.
2. L. Zhongwan: Mathematical Logic for Computer Science, World Scientific, Singapore, 1989.
3. D. Ebbinghaus, J. Flum and W. Thomas:Mathematical Logic, Springer-Verlag.
4. G. Boolos, J. P. Burgess, R.C. Jeffrey, Computability and Logic, Cambridge University Press.
5. Yu. I. Manin, A Course in Mathematical Logic for Mathematicians, Springer.
6. M. Davis, Computability and Unsolvability, Dover.
7. Any text recommended by the Instructor.

3. Combinatorial Optimization — 2 credit

Introduction: Optimization problems, neighbourhoods, local and global optima, convex sets and functions, simplex method, degeneracy; duality and dual simplex algorithm, computational considerations for the simplex and dual simplex algorithms-Dantzig-Wolfe algorithms.

Integer Linear Programming: Cutting plane algorithms, branch and bound technique and approximation algorithms for travelling salesman problem.

Books Recommended

1. C.H. Papadimitriou and K. Steiglitz, Combinatorial Optimization: Algorithms and Complexity, Prentice-Hall of India, 2006
2. K. Lange, Optimization, Springer, 2004.
3. Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, John Wiley and Sons, 2004.
4. H.A. Taha, Operations Research: An Introduction, 8th Ed., Prentice Hall, 2006.

4. Boolean Algebras — 2 credit

Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, maximal and minimal elements, lattices as ordered sets, complete lattices, lattices as algebraic structures, sublattices, products and homomorphisms.

Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal forms of Boolean polynomials, Quinn-McCluskey method,

Karnaugh diagrams, switching circuits and applications of switching circuits.

Books Recommended

1. B A. Davey and H.A. Priestley, *Introduction to Lattices and Order,* Cambridge University Press, Cambridge, 1990.
2. Rudolf Lidl and Günter Pilz, *Applied Abstract Algebra,* 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

5. Image and Video Processing — 2 credit

Fundamentals of Image processing and Image Transforms: Basic steps of Image processing system sampling and quantization of an Image – Basic relationship between pixels Image Transforms: 2 – D Discrete Fourier Transform, Discrete Cosine Transform (DCT), Discrete Wavelet transforms. Image Processing Techniques: Image Enhancement: Spatial Domain methods: Histogram Processing, Fundamentals of Spatial Filtering, Smoothing Spatial filters, Sharpening Spatial filters Frequency Domain methods: Basics of filtering in frequency domain, image smoothing, image sharpening, selective filtering Image Segmentation: Segmentation concepts, point, line and Edge detection, Thresholding, region based segmentation Image Compression Image compression fundamentals – coding Redundancy, spatial and temporal redundancy. Compression models : Lossy and Lossless, Huffmann coding, Arithmetic coding, LZW coding, run length coding, Bit Plane coding, transform coding, predictive coding , wavelet coding, JPEG standards Basic Steps of Video Processing: Analog video, Digital Video, Time varying Image Formation models : 3D motion models, Geometric Image formation , Photometric Image formation, sampling of video signals, filtering operations 2-D Motion Estimation: Optical flow, general methodologies, pixel based motion estimation, Block matching algorithm, Mesh based motion Estimation, global Motion Estimation, Region based motion estimation, multi resolution motion estimation. Waveform based coding, Block based transform coding, predictive coding, Application of motion estimation in video coding.

Books Recommended

1. Gonzaleze and Woods ,"Digital Image Processing", 3rd edition , Pearson.
2. Yao Wang, JornOstermann, Ya-Qin Zhang, 'Video Processing and Communications', Prentice Hall, 2002.
3. Alan C.Bovik, 'The Essential Guide to Video Processing', Elsevier Science, edition 2, 2009.
4. A. Murat Tekalp, 'Digital Video Processing', Prentice Hall, edition 1, 1996.
5. M. Tekalp ,"Digital video Processing", Prentice Hall International
6. Relf, Christopher G.,"Image acquisition and processing with LabVIEW", CRC press
7. Anerozdemi R, "Inverse Synthetic Aperture Radar Imaging with MATLAB Algorithms", John Wiley & Sons
8. Chris Solomon, Toby Breckon, "Fundamentals of Digital Image Processing A Practical Approach with Examples in Matlab", John Wiley & Sons.