Proposed Syllabus and Scheme of Examination

for

B.Sc. (Hons.) Applied Mathematics

submitted to

University Grants Commission
New Delhi

under the

Choice Based Credit System

May 2015
### Proposed Scheme for Choice Based Credit System in B.Sc. (Hons.) Applied Mathematics

<table>
<thead>
<tr>
<th>Semester</th>
<th>Core Course (14)</th>
<th>Ability Enhancement Compulsory Course (AECC)(2)</th>
<th>Skill Enhancement Course (SEC) (2)</th>
<th>Discipline Specific Elective (DSE) (4)</th>
<th>Generic Elective (GE) (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1 Calculus (P)</td>
<td>AECC1</td>
<td></td>
<td></td>
<td>GE1</td>
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<tr>
<td></td>
<td>C2 Algebra</td>
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<tr>
<td>2</td>
<td>C3 Real Analysis</td>
<td>AECC2</td>
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<td>GE2</td>
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<td></td>
<td>C4 Differential Equations (P)</td>
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<tr>
<td>3</td>
<td>C5 Theory of Real Functions</td>
<td>SEC1</td>
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<td>GE3</td>
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<tr>
<td></td>
<td>C6 Group Theory</td>
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<td></td>
<td>C7 PDE and Systems of ODE (P)</td>
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<tr>
<td>4</td>
<td>C8 Multivariate Calculus</td>
<td>SEC2</td>
<td></td>
<td></td>
<td>GE4</td>
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<td></td>
<td>C9 Complex Analysis</td>
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<td>C10 Rings and Linear Algebra</td>
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<td>5</td>
<td>C11 Mechanics</td>
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<td>DSE-1</td>
<td>DSE-2</td>
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<td></td>
<td>C12 Numerical Methods and Programming (P)</td>
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<td>6</td>
<td>C13 Integral Equations and Calculus of Variation</td>
<td>DSE-3</td>
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<td>C14 Laplace Transform (P)</td>
<td>DSE-4</td>
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(P) means course with practicals

Note: Institutions opting for both B.Sc. (Hons.) Mathematics and B.Sc. (Hons.) Applied Mathematics shall have first two semesters common.

**Discipline Specific Electives (DSE)**

**Choices for DSE 1 (choose one)**

1. Number Theory
2. Graph Theory
3. Linear Programming

**Choices for DSE 2 (choose one)**

1. Control Theory
2. Approximation Theory
3. Combinatorial Optimization

**Choices for DSE 3 (choose one)**

1. Mathematical Modeling
2. Coding Theory
3. Wavelet Theory

**Choices for DSE 4 (choose one)**

1. Bio-Mathematics
2. Stochastic Processes
3. Difference Equations

**Skill Enhancement Course (SEC)**

**Choices for SEC 1 (choose one)**

1. Electronic Commerce
2. Computer Graphics (P)
3. Operating Systems
Choices for SEC 2 (choose one)

1. Latex and Web Designing (P)
2. Transportation and Game Theory
3. Fuzzy Sets and Logics

Generic Electives (GE)

Choices for GE 1 (choose one)

1. Object Oriented Programming in C++
2. Finite Element Methods

Choices for GE 2 (choose one)

1. Mathematical Finance
2. Econometrics

Choices for GE 3 (choose one)

1. Digital Signal Processing
2. Neural Networks
3. Dynamical Systems

Choices for GE 4 (choose one)

1. Industrial Mathematics
2. Statistical Techniques
3. Modeling and Simulation
Details of courses under B.Sc. (Hons.) Applied Mathematics

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
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<tr>
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<td>Theory + Practical</td>
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I. Core Course
(14 Papers)

- 14×4 = 56
- 14×5 = 70

Core Course Practical / Tutorial*
(14 Papers)

- 14×2 = 28
- 14×1 = 14

II. Elective Course (8 Papers)

A.1. Discipline Specific Elective
(4 Papers)

- 4×4 = 16
- 4×5 = 20

A.2. Discipline Specific Elective
Practical/ Tutorial*
(4 Papers)

- 4×2 = 8
- 4×1 = 4

B.1. Generic Elective/
Interdisciplinary
(4 Papers)

- 4×4 = 16
- 4×5 = 20

B.2. Generic Elective
Practical/ Tutorial*
(4 Papers)

- 4×2 = 8
- 4×1 = 4

- Optional Dissertation or project work in place of one Discipline Specific Elective Paper (6 credits) in 6th Semester
### III. Ability Enhancement Courses

1. **Ability Enhancement Compulsory Courses (AECC)**
   - **(2 Papers of 2 credit each)**
   - Environmental Science English/MIL Communication
   - $2 \times 2 = 4$
   - $2 \times 2 = 4$

2. **Skill Enhancement Courses (SEC)**
   - **(Minimum 2)**
   - **(2 Papers of 2 credit each)**
   - $2 \times 2 = 4$
   - $2 \times 2 = 4$

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<tbody>
<tr>
<td><strong>Total credit</strong></td>
<td><strong>140</strong></td>
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<td><strong>140</strong></td>
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</tbody>
</table>

Institute should evolve a system/policy about ECA/ General Interest/ Hobby/ Sports/ NCC/ NSS/ related courses on its own.

* wherever there is a practical there will be no tutorial and vice-versa
C 1.1 Calculus

Hyperbolic functions, higher order derivatives, Leibniz rule and its applications to problems of type $e^{ax+b}\sin x$, $e^{ax+b}\cos x$, $(ax+b)^n\sin x$, $(ax+b)^n\cos x$, concavity and inflection points, asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standard curves, L’Hospital’s rule, applications in business, economics and life sciences.

Reduction formulae, derivations and illustrations of reduction formulae of the type $\int \sin nx \, dx$, $\int \cos nx \, dx$, $\int \tan nx \, dx$, $\int \sec nx \, dx$, $\int (\log x)^n \, dx$, $\int \sin^n x \sin^m x \, dx$, volumes by slicing, disks and washers methods, volumes by cylindrical shells, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution.

Techniques of sketching conics, reflection properties of conics, rotation of axes and second degree equations, classification into conics using the discriminant, polar equations of conics. Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions, tangent and normal components of acceleration, modeling ballistics and planetary motion, Kepler’s second law.

List of Practicals (using any software)

(i) Plotting of graphs of function $e^{ax+b}$, $\log(ax+b)$, $1/(ax+b)$, $\sin(ax+b)$, $\cos(ax+b)$, $|ax+b|$ and be able to find the effect of $a$ and $b$ on the graph.

(ii) Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.

(iii) Sketching parametric curves (Eg. Trochoid, cycloid, epicycloids, hypocycloid).

(iv) Obtaining surface of revolution of curves.

(v) Tracing of conics in Cartesian coordinates/ polar coordinates.

(vi) Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, hyperbolic paraboloid using Cartesian co-ordinates.

(vii) Matrix operation (addition, multiplication, inverse, transpose).

Books Recommended


C 1.2 Algebra

Polar representation of complex numbers, $n^{th}$ roots of unity, De Moivre’s theorem for rational indices and its applications.

Equivalence relations, Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set, Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm, Congruence relation between integers, Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic.

Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation $Ax=b$, solution sets of linear systems, applications of linear systems, linear independence.

Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspaces of $\mathbb{R}^n$, dimension of subspaces of $\mathbb{R}^n$ and rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix.

Books Recommended


C 2.1 Real Analysis


Infinite series, convergence and divergence of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy’s $n^{th}$ root test, Integral test, Alternating series, Leibnitz test, Absolute and Conditional convergence.

Books Recommended


C 2.2 Differential Equations

Differential equations and mathematical models. General, particular, explicit, implicit and singular solutions of a differential equation. Exact differential equations and integrating factors, separable equations and equations reducible to this form, linear equation and Bernoulli equations, special integrating factors and transformations.

Introduction to compartmental model, exponential decay model, lake pollution model (case study of Lake Burley Griffin), drug assimilation into the blood (case of a single cold pill, case of a course of cold pills), exponential growth of population, limited growth of population, limited growth with harvesting.

General solution of homogeneous equation of second order, principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler’s equation, method of undetermined coefficients, method of variation of parameters.

Equilibrium points, Interpretation of the phase plane, predatory-prey model and its analysis, epidemic model of influenza and its analysis, battle model and its analysis.

List of Practicals (using any software)

1. Plotting of second order solution family of differential equation.
2. Plotting of third order solution family of differential equation.
3. Growth model (exponential case only).
4. Decay model (exponential case only).
5. Lake pollution model (with constant/seasonal flow and pollution concentration).
6. Case of single cold pill and a course of cold pills.
7. Limited growth of population (with and without harvesting).
8. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
10. Battle model (basic battle model, jungle warfare, long range weapons).
12. Study the convergence of sequences through plotting.
13. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
14. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.
15. Cauchy’s root test by plotting $n^{th}$ roots.

16. Ratio test by plotting the ratio of $n^{th}$ and $(n+1)^{th}$ term.

Books Recommended:


C 3.1 Theory of Real Functions


Differentiability of a function, Caratheodory’s theorem, algebra of differentiable functions. Relative extrema, interior extremum theorem. Rolle’s theorem, Mean value theorem, intermediate value property of derivatives, Darboux’s theorem. Applications of mean value theorem and Taylor’s theorem to inequalities.

Cauchy’s mean value theorem. Taylor’s theorem with Lagrange’s form of remainder, Taylor’s theorem with Cauchy’s form of remainder.

Riemann integration, Riemann conditions of integrability. Riemann sum and definition of Riemann integral through Riemann sums; equivalence of two definitions; Riemann integrability of monotone and continuous functions, Properties of the Riemann integral.

Improper integrals; Convergence of Beta and Gamma functions.

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions.

Limit superior and Limit inferior. Power series, radius of convergence.

Remark: Emphasis should be given on problems and applications of results.

Books Recommended

5. Charles G. Denlinger, Elements of Real Analysis, Jones and Bartlett (Student Edition), 2011.
C 3.2 Group Theory

Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), elementary properties of groups. Subgroups and examples of subgroups, centralizer, normalizer, center of a group, product of two subgroups.

Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation for permutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange’s theorem and consequences including Fermat’s Little theorem.

External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy’s theorem for finite abelian groups.

Group homomorphisms, properties of homomorphisms, Cayley’s theorem, properties of isomorphisms, First, Second and Third isomorphism theorems. Automorphism, inner automorphism, automorphism groups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups,

Characteristic subgroups, Commutator subgroup and its properties.

Remark: Emphasis should be given on problems and applications of results.

Books Recommended


C 3.3 PDE and Systems of ODE


List of Practicals (using any software)

(i) Solution of Cauchy problem for first order PDE.

(ii) Finding the characteristics for the first order PDE.

(iii) Plot the integral surfaces of a given first order PDE with initial data.

(iv) Solution of wave equation \( \frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} = 0 \) for the following associated conditions

(a) \( u(x,0) = \phi(x), \ u_t(x,0) = \psi(x), \ x \in \mathbb{R}, \ t > 0 \)
(b) \( u(x,0) = \phi(x), \ u_t(x,0) = \psi(x), \ u(0,t) = 0, \ x \in (0,\infty), \ t > 0 \)
(c) \( u(x,0) = \phi(x), \ u_t(x,0) = \psi(x), \ u_x(0,t) = 0, \ x \in (0,\infty), \ t > 0 \)
(d) \( u(x,0) = \phi(x), \ u_t(x,0) = \psi(x), \ u(0,t) = 0, \ u(1,t) = 0, \ 0 < x < l, \ t > 0 \)

(v) Solution of wave equation \( \frac{\partial u}{\partial t} - k^2 \frac{\partial^2 u}{\partial x^2} = 0 \) for the following associated conditions

(a) \( u(x,0) = \phi(x), \ u(0,t) = a, \ u(l,t) = b, \ 0 < x < l, \ t > 0 \)
(b) \( u(x,0) = \phi(x), \ x \in \mathbb{R}, \ 0 < t < T \)
(c) \( u(x,0) = \phi(x), \ u(0,t) = a, \ x \in (0,\infty), \ t \geq 0 \)
Books Recommended


C 4.1 Multivariate Calculus

Use of Scientific Calculator is allowed.

Functions of several variables, limit and continuity of functions of two variables, Partial differentiation, total differentiability and differentiability, sufficient condition for differentiability.

Chain rule for one and two independent parameters, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes. Extrema of functions of two variables, method of Lagrange multipliers, constrained optimization problems, Definition of vector field, divergence and curl.

Double integration over rectangular region, double integration over non-rectangular region. Double integrals in polar co-ordinates, Triple integrals, Triple integral over a parallelepiped and solid regions volume by triple integrals, cylindrical and spherical co-ordinates. Change of variables in double integrals and triple integrals.

Line integrals, Applications of line integrals: Mass and Work. Fundamental theorem for line integrals, conservative vector fields, independence of path.

Green’s theorem, surface integrals, integrals over parametrically defined surfaces. Stoke’s theorem, The Divergence theorem.

Books Recommended


C 4.2 Complex Analysis

Limits, Limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings. Derivatives, differentiation formulas, Cauchy-Riemann equations, sufficient conditions for differentiability.


Laurent series and its examples, absolute and uniform convergence of power series, uniqueness of series representations of power series. Isolated singular points, residues, Cauchy’s residue theorem, residue at infinity. Types of isolated singular points, residues at poles and its examples, definite integrals involving sines and cosines.

List of Practicals (using any software)

(i) Declaring a complex number e.g. $z_1 = 3 + 4i, z_2 = 4 - 7i$. Discussing their algebra $z_1 + z_2$, $z_1 - z_2$, $z_1 \times z_2$ and $z_1 / z_2$ and then plotting them.

(ii) Finding conjugate, modulus and phase angle of an array of complex numbers. e.g., $z = [2 + 3i, 4 - 2i, 6 + 11i, 2 - 5i]$.

(iii) Compute the integral over a straight line path between the two specified end points e.g., $\int_C f(z)dz$, where C is the straight line path from $a + ib$ to $c + id$.

(iv) Perform contour integration e.g. $\int_C f(z)dz$, where C is the contour given by $g(x, y) = 0$.

(v) Plotting of the complex functions like $f(z) = z, f(z) = z^3, f(z) = \left(z^4 - 1\right)^{1/4}$, etc.

(vi) Finding the residues of the complex function.

(vii) Taylor series expansion of a given function $f(z)$ around a given point $z$, given the number of terms in the Taylor series expansion. Hence comparing the function and its Taylor series expansion by plotting the magnitude of each. For example

(a) $f(z) = \exp(z)$ around $z = 0, n = 40$

(b) $f(z) = \exp(z^2)$ around $z = 0, n = 160$, etc.
(viii) To perform Laurent series expansion of a given function $f(z)$ around a given point $z$, e.g., $f(z) = (\sin z - 1)/z^4$ around $z = 0$, $f(z) = \cot(z)/z^4$ around $z = 0$, etc.

(ix) Computing the Fourier series, Fourier sine series and Fourier cosine series of a function and plotting their graphs.

**Books Recommended**


C 4.3 Rings and Linear Algebra

Definition and examples of rings, properties of rings, integral domains and fields, characteristic of a ring.

Ideals, ideal generated by a subset of a ring, operations on ideals, prime and maximal ideals.

Ring homomorphisms, properties of ring homomorphisms, polynomial rings over commutative rings, division algorithm, Eisenstein criterion.

Vector spaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.

Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, algebra of linear transformations.

Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigenspaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, the minimal polynomial for a linear operator. Inner product spaces and norms.

Remark: Emphasis should be given on problems and applications of results.

Books Recommended

C 5.1 Mechanics

Moment of a force about a point and an axis, couple and couple moment, Moment of a couple about a line, resultant of a force system, distributed force system, free body diagram, free body involving interior sections, general equations of equilibrium, two point equivalent loading, problems arising from structures, static indeterminacy.

Laws of Coulomb friction, application to simple and complex surface contact friction problems, transmission of power through belts, screw jack, wedge, first moment of an area and the centroid, other centers, Theorem of Pappus-Guldinus, second moments and the product of area of a plane area, transfer theorems, relation between second moments and products of area, polar moment of area, principal axes.

Conservative force field, conservation for mechanical energy, work energy equation, kinetic energy and work kinetic energy expression based on center of mass, moment of momentum equation for a single particle and a system of particles, translation and rotation of rigid bodies, Chasles’ theorem, general relationship between time derivatives of a vector for different references, relationship between velocities of a particle for different references, acceleration of particle for different references.

Books Recommended


C 5.2 Numerical Methods and Programming


Lagrange and Newton interpolation: linear and higher order, finite difference operators.

Numerical differentiation: forward difference, backward difference and central difference. Integration: trapezoidal rule, Simpson’s rule, Euler’s method.

Note: Emphasis is to be laid on the algorithms of the above numerical methods.

List of Practicals (using any software)

(i) Calculate the sum $\frac{1}{1} + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \ldots + \frac{1}{N}$.
(ii) To find the absolute value of an integer.
(iii) Enter 100 integers into an array and sort them in an ascending order.
(iv) Bisection Method.
(v) Newton Raphson Method.
(vi) Secant Method.
(vii) Regulai Falsi Method.
(viii) LU decomposition Method.
(ix) Gauss-Jacobi Method.
(x) SOR Method or Gauss-Siedel Method.
(xi) Lagrange Interpolation or Newton Interpolation.
(xii) Simpson’s rule.

Note: For any of the CAS, Data types—simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Books Recommended

C 6.1 Integral Equations and Calculus of Variation


Fredholm Integral Equations: Solution of integral equations with separable kernels, Eigen values and Eigen functions. Solution by the successive approximations, Neumann series and resolvent kernel. Solution of integral equations with symmetric kernels, Hilbert-Schmidt theorem, Green’s function approach.

Classical Fredholm Theory: Fredholm method of solution and Fredholm theorems.


Calculus of Variations: Basic concepts of the calculus of variations such as functionals, extremum, variations, function spaces, the brachistochrone problem.

Necessary condition for an extremum, Euler’s equation with the cases of one variable and several variables, Variational derivative. Invariance of Euler’s equations. Variational problem in parametric form.

General Variation: Functionals dependent on one or two functions, Derivation of basic formula, Variational problems with moving boundaries, Broken extremals: Weierstrass–Erdmann conditions.

Books Recommended

C 6.2 Laplace Transform

Laplace Transform: Laplace of some standard functions, Existence conditions for the Laplace Transform, Shifting theorems, Laplace transform of derivatives and integrals, Inverse Laplace transform and their properties, Convolution theorem, Initial and final value theorem, Laplace transform of periodic functions, error functions, Heaviside unit step function and Dirac delta function, Applications of Laplace transform to solve ODEs and PDEs.

Finite Laplace Transform: Definition and properties, Shifting and scaling theorem.

Z-Transform: Z-transform and inverse Z-transform of elementary functions, Shifting theorems, Convolution theorem, Initial and final value theorem, Application of Z-transforms to solve difference equations.

Hankel Transform: Basic properties of Hankel Transform, Hankel Transform of derivatives, Application of Hankel transform to PDE.

Mellin Transform: Definition and properties of Mellin transform, Shifting and scaling properties, Mellin transforms of derivatives and integrals, Applications of Mellin transform.

Fourier series: Trigonometric Fourier series and its convergence, Fourier series of even and odd functions, Gibbs phenomenon, Fourier half-range series, Parseval’s identity, Complex form of Fourier series.

Fourier Transforms: Fourier integrals, Fourier sine and cosine integrals, Complex form of Fourier integral representation, Fourier transform, Fourier transform of derivatives and integrals, Fourier sine and cosine transforms and their properties, Convolution theorem, Application of Fourier transforms to Boundary Value Problems.

Books Recommended

DSE 1.1 Number Theory

Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat’s Little theorem, Wilson’s theorem.

Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Möbius Inversion formula, the greatest integer function, Euler’s phi-function, Euler’s theorem, reduced set of residues, some properties of Euler’s phi-function.

Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler’s criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation \( x^2 + y^2 = z^2 \), Fermat’s Last theorem.

Books Recommended


DSE 1.2 Graph Theory

Definition, examples and basic properties of graphs, pseudographs, complete graphs, bi-partite graphs, isomorphism of graphs, paths and circuits, Eulerian circuits, Hamiltonian cycles, the adjacency matrix, weighted graph, travelling salesman’s problem, shortest path, Dijkstra’s algorithm, Floyd-Warshall algorithm.

Applications of paths and circuits: the Chinese postman problem, digraphs, the Bellman-Ford algorithm, tournaments, directed network, scheduling problems, definition, examples and basic properties of trees, spanning trees, minimum spanning tree algorithms, Kruskal’s algorithm, Prim’s algorithm, acyclic digraphs, Bellman’s algorithm.

Planar graphs, colouring of graphs, statement of the four-colour theorem, the five colour theorem, circuit testing, facilities design, flows and cuts, construction of flows, constructing maximal flows, rational weights, applications of directed networks, matchings.

Books Recommended

**DSE 1.3 Linear Programming**

Linear Programming Problems, Graphical Approach for Solving some Linear Programs. Convex Sets, Supporting and Separating Hyperplanes. Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.

Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual, sensitivity analysis.

**Books Recommended**


DSE 2.1 Control Theory

Mathematical models of control systems, State space representation, Autonomous and non autonomous systems, State transition matrix, Peano series solution of linear dynamical system.

Block diagram, Transfer function, Realization, Controllability, Kalman theorem, Controllability Grammian, Control computation using Grammian matrix, Observability, Duality theorems.

Discrete control systems, Controllability and Observability results for discrete systems.


Control systems on Hilbert spaces, Semi group theory, Mild solution, Control of a linear system.

Books Recommended

DSE 2.2 Approximation Theory


The Weierstrass theorem, Bernstein polynomials, Korovkin theorem, Algebraic and trigonometric polynomials of the best approximation, Lipschitz class, Modulus of continuity, Integral modulus of continuity and their properties.

Bernstein’s inequality, Jackson’s theorems and their converse theorems, Approximation by means of Fourier series.

Positive linear operators, Monotone operators, Simultaneous approximation, $p L$ -approximation, Approximation of analytic functions.

Books Recommended

DSE 2.3 Combinatorial Optimization

Introduction: Optimization problems, neighborhoods, 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 traveling salesman problem.


Books Recommended


DSE 3.1 Mathematical Modeling

Power series solution of a differential equation about an ordinary point, solution about a regular singular point, Bessel’s equation and Legendre’s equation, Laplace transform and inverse transform, application to initial value problem up to second order.

Monte Carlo Simulation Modeling: simulating deterministic behavior (area under a curve, volume under a surface), Generating Random Numbers: middle square method, linear congruence, Queuing Models: harbor system, morning rush hour, Overview of optimization modeling, Linear Programming Model: geometric solution algebraic solution, simplex method, sensitivity analysis.

List of Practicals (using any software)

(i) Plotting of Legendre polynomial for \( n = 1 \) to 5 in the interval \([0,1]\). Verifying graphically that all the roots of \( P_n(x) \) lie in the interval \([0,1]\).
(ii) Automatic computation of coefficients in the series solution near ordinary points
(iii) Plotting of the Bessel’s function of first kind of order 0 to 3.
(iv) Automating the Frobenius Series Method
(v) Random number generation and then use it for one of the following (a) Simulate area under a curve (b) Simulate volume under a surface
(vi) Programming of either one of the queuing model (a) Single server queue (e.g. Harbor system) (b) Multiple server queue (e.g. Rush hour)
(vii) Programming of the Simplex method for 2/3 variables.

Books Recommended

DSE 3.2 Coding Theory

The communication channel, The coding problem, Block codes, Hamming metric, Nearest neighbour decoding, Linear codes, Generator and Parity-check matrices, Dual code, Standard array decoding, Syndrome decoding.

Hamming codes, Golay codes, Reed-Muller codes, Codes derived from Hadamard matrices.
Bounds on codes: Sphere packing bound, Perfect codes, Gilbert-Varshamov bound, Singleton bound, MDS codes, Plotkin bound.

Weight distributions of codes, Mac Williams identities. Algebra of polynomials, Residue class rings, Finite fields, Cyclic codes, Generator polynomial and check polynomial, Defining set of a cyclic code.

BCH bound, Encoding and decoding of cyclic codes, Hamming and Golay codes as cyclic codes, BCH codes, Reed-Solomon codes, Quadratic residue codes, Graphical codes, Convolutional codes.

Books Recommended

**DSE 3.3 Wavelet Theory**

Review of basic concepts and theorems of Functional analysis and Lebesgue theory.

Advanced Fourier Analysis: Fourier transform (F.T.) of functions in $L_1(R)$. Basic properties of F.T. of functions in $L_2(R)$. Inverse Fourier transform, Convolution, Approximate identity. Auto correlation of functions in $L_2(R)$, F.T. of functions in $L_1(R) \cap L_2(R)$. Various versions of Parseval’s identity (P.I.) of functions in $L_1(R) \cap L_2(R)$. Evaluation of improper integrals using P.I., Plancheral theorem.

Trigonometric Fourier Series (TFS) of functions of $L^1[0, 2\pi]$ and its complex form. Dirichlet conditions, Gibbs phenomenon, modulus of continuity, integral modulus of continuity. Convergence of TFS in $L_1[0, 2\pi]$, Bessel’s inequality for functions of $L_2[0, 2\pi]$. Summability of TFS. The Poisson’s summation formula and its applications.

Time Frequency Analysis: Window functions and their examples. Windowed functions. The Gabor transform STFS, the uncertainty principal, the classical Shannon sampling theorem, frames, exact and tight frames.

Wavelet Transform: Isometric isomorphism between $L_2$ and $L_2[0, 2\pi]$, wavelet transform, wavelet series. Basic wavelets (Haar/Shannon/Daubechies), integral wavelet, orthogonal wavelets, multi-resolution analysis, reconstruction of wavelets and applications.

**Books Recommended**

DSE 4.1 Bio-Mathematics


Books Recommended

DSE 4.2 Stochastic Processes

Introduction to stochastic processes, Poisson Process: Inter arrival and waiting time distributions, conditional distributions of the arrival times, non-homogeneous Poisson process, compound Poisson random variables and Poisson processes, conditional Poisson processes.


Martingales: Introduction, stopping times, Azuma’s inequality for martingales, submartingales, supermartingales, martingale convergence theorem.

Brownian Motion and other Markov Processes: Introduction, hitting time, maximum variable, Arc sine laws, variations on Brownian motion, Brownian motion with drift, backward and forward diffusion equations.

Books Recommended

DSE 4.3 Difference Equations


Linear Difference Equations: First Order Equations, General Results for Linear Equations, Solving Linear Equations, Applications, Equations with Variable Coefficients, Nonlinear Equations that can be Linearized, the z-Transform.


Books Recommended


SEC 1.1 Electronic Commerce

Building Blocks of Electronic Commerce: Introduction, internet and networking technologies, Internet and network protocols, web server scalability, software technologies for building E-commerce applications, distributed objects, object request brokers, component technology, web services, web application architectures, design of auctions, optimization algorithms for market places, multi-agent systems. Global e-Commerce and Law: Cyber law in India. Comparative evaluation of Cyber laws of certain countries.

Books Recommended


SEC 1.2 Computer Graphics

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


SEC 1.3 Operating Systems

Introduction: Operating System as a resource manager, operating system classification, system calls, traps, architectures for operating systems.


File Management: Overview of file management system, disk space management, directory structures. Protection domains, access control lists, protection models.

Books Recommended:
SEC 2.1 Latex and Web Designing

LaTeX: Elements of LaTeX, typesetting mathematics, graphics in LaTeX, PSTricks, Beamer presentation

HTML: HTML basics, creating simple web pages, images and links, design of web pages, CSS, MathJaX

Books Recommended


SEC 2.2 Transportation and Game Theory


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

Books Recommended


SEC 2.3 Fuzzy Sets and Logics

Fuzzy Sets and Uncertainty: Uncertainty and information, fuzzy sets and membership functions, chance versus fuzziness, properties of fuzzy sets, fuzzy set operations.

Fuzzy Relations: Cardinality, operations, properties, fuzzy Cartesian product and composition, fuzzy tolerance and equivalence relations, forms of composition operation.

Fuzzification and Defuzzification: Various forms of membership functions, fuzzification, defuzzification to crisp sets and scalars.

Fuzzy Logic and Fuzzy Systems: Classic and fuzzy logic, approximate reasoning, Natural language, linguistic hedges, fuzzy rule based systems, graphical technique of inference.


Fuzzy Optimization: One dimensional fuzzy optimization, fuzzy concept variables and casual relations, fuzzy cognitive maps, agent based models.

Fuzzy Control Systems: Fuzzy control system design problem, fuzzy engineering process control, fuzzy statistical process control, industrial applications.

Books Recommended


GE 1.1 Object Oriented Programming in C++


Abstract data types, Class Component, Object & Class, Constructors Default and Copy Constructor, Assignment operator deep and shallow coping, Access modifiers – private, public and protected. Implementing Class Functions within Class declaration or outside the Class declaration, instantiation of objects, Scope resolution operator, Working with Friend Functions, sing Static Class members. Understanding Compile Time Polymorphism function overloading

Rules of Operator Overloading (Unary and Binary) as member function/friend function, Implementation of operator overloading of Arithmetic Operators, Overloading Output/ Input, Prefix/ Postfix Increment and decrement Operators, Overloading comparison operators, Assignment, subscript and function call Operator , concepts of name spaces.

Practical to be performed in lab.

Books Recommended

GE 1.2 Finite Element Methods

Introduction to finite element methods, comparison with finite difference methods. Methods of weighted residuals, collocations, least squares and Galerkin’s method. 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

GE 2.1 Mathematical Finance

Basic principles: Comparison, arbitrage and risk aversion, Interest (simple and compound, discrete and continuous), time value of money, inflation, net present value, internal rate of return (calculation by bisection and Newton-Raphson methods), comparison of NPV and IRR Bonds, bond prices and yields, Macaulay and modified duration, term structure of interest rates: spot and forward rates, explanations of term structure, running present value, floating-rate bonds, immunization, convexity, putable and callable bonds.

Asset return, short selling, portfolio return, (brief introduction to expectation, variance, covariance and correlation), random returns, portfolio mean return and variance, diversification, portfolio diagram, feasible set, Markowitz model (review of Lagrange multipliers for 1 and 2 constraints), Two fund theorem, risk free assets, One fund theorem, capital market line, Sharpe index. Capital Asset Pricing Model (CAPM), betas of stocks and portfolios, security market line, use of CAPM in investment analysis and as a pricing formula, Jensen’s index.

Books Recommended


GE 2.2 Econometrics

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


**GE 3.1 Digital Signal Processing**


Transform-Domain Representation of Signals: the Discrete-Time Fourier Transform, Discrete Fourier Transform, DFT properties, computation of the DFT of real sequences, Linear Convolution using the DFT. Z-transforms, Inverse z-transform, properties of z transform, transform domain representations of random signals, FFT. Transform-Domain Representation of LTI Systems: the frequency response, the transfer function, types of transfer function, minimum-phase and maximum-phase transfer functions.

Digital Processing of continuous-time signals: sampling of continuous signals, analog filter design, anti-aliasing, filter design, sample-and-hold circuits, A/D and D/A converter, reconstruction filter design. Digital Filter Structure: Block Diagram representation, Signal Flow Graph Representation, Equivalent Structures, FIR Digital Filter Structures, IIR Filter Structures. transfer, modes of data transfer, priority interrupt, direct memory access, input-output processor.


**Books Recommended**

GE 3.2 Neural Networks

Introduction: Neuron as basic unit of Neurobiology, McCulloch-Pitts model, Hebbian Hypothesis; limitations of single-layered neural networks.


Books Recommended:

3. C.M. Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995.
GE 3.3 Dynamical Systems

Linear Dynamical Continuous Systems: First order equations, existence uniqueness theorem, growth equation, logistic growth, constant harvesting, Planar linear systems, equilibrium points, stability, phase space, n-dimensional linear systems, stable, unstable and center spaces.

Nonlinear autonomous Systems: Motion of pendulum, local and global stability, Liapunov method, periodic solution, Bendixson's criterion, Poincare Bendixson theorem, limit cycle, attractors, index theory, Hartman Grobman theorem, nonhyperbolic critical points, center manifolds, normal forms, Gradient and Hamiltonian systems.


Books Recommended


GE 4.1 Industrial Mathematics

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 fundamental 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


GE 4.2 Statistical Techniques

Probability: Basic concepts and definitions (Classical and Axiomatic definition), random variable, probability density function, probability mass function, distribution function and their properties, mathematical expectation, conditional expectation, moment generating function, Characteristic Function, Chebyshev’s inequality.

Various discrete and continuous probability distributions: Uniform (continuous and discrete), Binomial, Negative Binomial, Poisson, Exponential, Erlang, Gamma, Normal, t distribution and F-distribution, Bivariate normal distribution (Marginal and Conditional distributions), Weak Law of Large Numbers, Central Limit Theorem. Simple random sampling with and without replacement, Random number generation using inverse transformation technique (exponential distribution, gamma distribution)

Statistical Testing and Estimation Techniques: Properties of good estimator- unbiasedness, consistency, sufficiency, completeness, efficiency; Minimum variance unbiased estimators, Cramer Rao Inequality, Method of Maximum likelihood, method of Moments, Confidence Intervals for mean, variance and proportions. Large sample tests for mean and proportion, chi square test for goodness of fit, Tests based on t and F-distributions.

Correlation and Regression: Least square method for curve fitting, multiple regression (three variables only), Partial and multiple Correlation (for three variables only).

Books Recommended


GE 4.3 Modeling and Simulation


Introduction to Continuous Models, Carbon Dating, Drug Distribution in the Body, Growth and decay of current in a L-R Circuit, Horizontal Oscillations, Vertical Oscillations, Damped Force Oscillation, Dynamics of Rowing, Combat Models, Mathematical Model of Influenza Infection (within host), Epidemic Models (SI, SIR, SIRS, SIC), Spreading of rumour model, Steady State solutions, Linearization and Local Stability Analysis, logistic and gomperzian growth, prey-predator model, Competition models, Numerical solution of the models and its graphical representation using EXCEL.

Fluid flow through a porous medium, heat flow through a small thin rod (one dimensional), Wave equation, Vibrating string, Traffic flow, Theory of Car-following, Crime Model, Linear stability Analysis: one and two species models with diffusion, Conditions for diffusive instability with examples.

Books Recommended