Gautam Buddha University
School of Vocational Studies and Applied Sciences
Mathematics Courses

Department of Applied Mathematics
M. Sc. Applied Mathematics

Session 2013-2014

Contents

Course Structure (M.Sc. Applied Mathematics)

Semester I

S.No.	Course Code	Course	Category	L	T	P	Credit
1	MA401	Linear Algebra	C	3	1	0	4
2	MA405	Real Analysis	C	3	1	0	4
3	MA407	Ordinary Differential Equations	C	3	1	0	4
4	MA409	Numerical Analysis	C	3	1	0	4
5	MA417	Number Theory	C	3	1	0	4
6	MA421	Introduction to MATLAB	SEC	0	0	3	2
7	EN521	Advanced course in Professional Communications	AECC	2	0	0	2
		Total Credits					**24**

Semester II

S.No.	Course Code	Course	Category	L	T	P	Credit
1	MA404	Abstract Algebra	C	3	1	0	4
2	MA406	Operations Research	C	3	1	0	4
3	MA408	Partial Differential Equations	C	3	1	0	4
4	MA410	Complex Analysis	C	3	1	0	4
5	MA414	Functional Analysis	C	3	1	0	4
6	MA416	Probability and Stochastic Process	C	3	1	0	4
		Total Credits					**24**

Semester III

S.No.	Course Code	Course	Category	L	T	P	Credit
1	—	Select any one course	GE	3	0	0	3
2	MA507	Optimization Techniques	C	3	1	0	4
3	MA513	Methods of Applied Mathematics	C	3	1	0	4
4	MA515	Numerical Solutions of ODE and PDE	C	3	1	0	4
5		DSE-I	DSE	3	0	0	3
6	MA519	Minor Project	Project	0	0	8	4
7	MA521	ODE and PDE lab using MATLAB	SEC	0	0	2	1
		Total Credits					**23**

Semester IV

S.No.	Course Code	Course	Category	L	T	P	Credit
1	—	DSE-II	DSE	3	0	0	3
2	MA508	Topology	C	3	1	0	4
3	—	DSE-III	DSE	3	0	0	3
4	MA520	Major Project	Project	0	0	30	15
5	GP502	General Proficiency		0	0	0	0
		Total Credits					**25**
Gray height		**Overall Credits**					**96**

Abbreviation: C: Core Courses, SEC: Skill Enhancement Course, AECC: Ability Enhancement Compulsory Course, GE: Generic Elective, DSE: Discipline Specific Elective

Core subjects

MA 401 (Linear Algebra)   Credit (L-T-P) : 4 (3- 1- 0)

Systems of linear equations. Vector spaces over field F, Subspaces, Sums and Direct Sum, Bases and Dimension, linear mappings and their matrix representation. Linear Functional, Dual Space, Annihilators, Transpose of a linear Mapping, Inner product spaces, Cauchy-Schwarz inequality, Orthogonality, Orthonormal basis, Gram-Schmidt process, Complex Inner Product Spaces, Normed Vector Spaces Polynomial of matrices, eigenvalues and eigenvectors, Diagonalization of matrices, Triangular form, invariance, Direct sum decomposition, Invariant direct sum, The primary decomposition theorem, Nilpotent Operator. Jordan canonical form, Cyclic Subspaces, Rational canonical form, Quotient Spaces.

Bibliography

[1] S. H. Friedberg, Arnold J Insel and Lawrence Spence, *Linear Algebra*, 4th ed., Pearson Education

[2] W. Cheney and D. Kincaid, *Linear Algebra: Theory and Applications*, 1^{st} Indian Edition, Jones and Bartlet, India

[3] K. Hoffman and R. Kunze, *Linear Algebra*. Prentice Hall of India.

[4] S. Roman, *Advanced Linear Algebra*. Springer.

[5] *Linear Algebra Schuam Series*. Tata Mc Graw Hill.

[6] P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, *First Course in Linear Algebra*. Wiley Eastern Ltd.

MA 405 (Real Analysis) Credit (L-T-P) : 4 (3- 1- 0)

Definition and existence of Riemann Stieltjes integral, properties of the integral, integration and differentiation, the fundamental theorem of calculus. Sequence and series of functions, point-wise and uniform convergence, Cauchy criterion for uniform convergence, Weierstrass M-test, Abel's and Dirichlet's tests for uniform convergence, uniform convergence and continuity, uniform convergence and Riemann Stieltjes integral, uniform convergence and differentiation, Weierstrass approximation theorem, Calculus of several variables, differentiation, Green, Stokes and Divergence theorems.
Proposal:
Definition and existence of Riemann Stieltjes integral, properties of the integral, Integrability of Continuous Functions
The Topology of Cartesian Spaces: Basic Idea of Innerproduct and norm, Open Sets, Closed Sets, Neighborhoods, The Nested Intervals and Bolzano-Weierstrass Theorems, Compact Sets, Connected Sets, The Theorems of Heine-Bore1 and Baire, CANTOR INTERSECTION THEOREM.
Sequence and series of functions, point-wise and uniform convergence, The Limif Superior. Cauchy criterion for uniform convergence, Weierstrass M-test, Abel's and Dirichlet's tests for uniform convergence, uniform convergence and continuity, uniform convergence and Riemann Stieltjes integral, uniform convergence and differentiation, Weierstrass approximation theorem, Calculus of several variables, The Derivative in R^P.

Bibliography

[1] W. Rudin, *Principles of Mathematical Analysis*, McGraw Hill.

[2] T. Apostol, *Mathematical Analysis*, Addison-Wesley.

[3] J. E. Marsden, A. Tromba, A. Weinstein-Basic, *Multivariate Calculus*, Springer Verlag.

[4] H. L. Royden, *Real Analysis*, Macmillan Publishing Company.

MA 407 (Ordinary Differential Equations) Credit (L-T-P) : 4 (3- 1- 0)

Review of solution methods for first order as well as second order equations, Euler-Cauchy Equations, Variation of parameter method, Wronskian, fundamental solutions, matrix exponential solution, Qualitative properties of the solutions of second order ODE, Normal form, Strum comparison, Separation theorems and oscillations, Initial Value Problems, Existence and uniqueness of solutions to first order equations: Picard's Theorem, Lipschitz condition, Gronwell's inequality, Power Series Method, Regular Singular Points, Frobenius Method, Boundary Value Problems, Orthonormal Functions, Sturm Liouville's Problems, Regular Sturm Liouville's Problems, Eigenvalues and Eigen Functions, Eigen Function Expansion, Singular Sturm Liouville's Problems, Adjoint equations, Lagrange's identity, Non-homogeneous Boundary Value Problems, Green's functions.

Bibliography

[1] G. F. Simmons, *Differential equations with applications and Historical Notes*, Second Edition, McGraw Hill, 1991

[2] Martin Braun, *Differential Equations and Their Applications : An Introduction to Applied Mathematics* (Texts in Applied Mathematics, Vol. 11)(Springer)

[3] W. E. Boyce and R. C. DiPrima, *Elementary Differential Equations and Boundary Value Problems*, Wiley, 2000.

[4] E. A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications, 1989.

[5] S. L. Ross, *Introduction to Ordinary Differential Equations*, 4th Edition, Wiley, 1989.

[6] G. Birkhoff and G. C. Rota, Ordinary *Differential Equations*, John Wiley & Sons, 1989.

MA 409 (Numerical Analysis) Credit (L-T-P) : 4 (3-1- 0)

Root finding problems for transcendental and polynomial equations - methods and analysis Method of Successive Substitution, Aitkens method, Newton-Raphson and modified Newton-Raphson method, Muller method, Chebyshev method, Bairstow's method,Graeffes-root squaring method, convergence analysis, Numerical solution of system of Linear Equations and Eigen Value Problems: Ill-conditioned systems and conditioned number; Block-iterative methods (Jacobi, Gauss-Seidel and SOR); Determination of optimal relaxation parameter; convergence analysis; Eigen value and eigen vectors; Jacobi method, Givens method and Householder method for symmetric matrices; Rutishausher method for arbitrary matrices; Power method; Inverse power method. Interpolation, Spline interpolation, Cubic spline interpolation, Lagrange Interpolation, Hermite's interpolation, Inverse interpolation, Least squares approximation and minimax approximation, Chebyshev approximation, Numerical differentiation, Numerical integration, Method of undetermined coefficients, Newton-Cotes and Gaussian quadratures, Gauss-Legendre Quadrature Formula, Gauss-Chebyshev Quadrature Formulae, Lobatto, Radau and Gauss-Laguerre Formula, Gauss-Hermite Formula, Richardson's Extrapolation, Euler-Maclaurin's formula, Optimum choice of length, composite integration; Romberg integration; Double integration.

Bibliography

[1] R. S. Gupta, *Elements of Numerical Analysis* Macmilan, 2009.

[2] J. B. Scarboraugh, *Numerical Mathematical Analysis*, Oxford & IBH Publishing Company, New Delhi.

[3] K. E. Atkinson, *Introduction to Numerical Analysis*, 2nd Edn., John Wiley, 1989.

[4] Curtis F. Gerald, Patrick O. Wheatley, *Applied Numerical Analysis*, Pearson, 2003.

[5] R.L. Burden and J.D. Faires, Numerical Analysis, 7th Edit., Thomson, New York, 2007.

MA 411 (Methods of Applied Mathematics-I) Credit

(L-T-P) : 4 (3- 1- 0)

Review: Elementary Functions, Special Functions, Power Series Method of Differential Equations, Ordinary and Singular points. Bessel's Equation: General solution of Bessel Equations, Recurrence relations, Orthogonal sets of Bessel functions, Modified Bessel functions, Applications, Legendre's Equation: General solution of Legendre equation, Legendre polynomials, Associated Legendre polynomials, Rodrigues formula, Orthogonality of Legendre polynomials, Application, Fourier Analysis: Generalized Fourier series, Fourier Cosine series, Fourier Sine series, Fourier integrals, Fourier transform, Z-transform, Hankel transform, Mellin transform

Bibliography

[1] G. F. Simmons, Differential Equations with Applications, Tata Mc Graw-Hill, 2003

[2] G. N. Watson- A Treatise on the Theory of Bessel Functions, Cambridge University Press, 1944.

[3] G. F. Roach- Green's Functions, Cambridge University Press, 1995.

[4] A. D. Poularikas- The Transforms and Applications Handbook, CRC Press, 1996.

[5] J. W. Brown and R. Churchill- Fourier Series and Boundary Value Problems, McGraw Hill, 1993.

MA 413 (Fundamentals of Computer Programming)

Credit (L-T-P) : 2 (2- 0- 0)

Introduction to digital computers; introduction to programming - variables, assignments; expressions; input/output; conditionals and branching; iteration; functions; recursion; arrays; introduction to pointers; structures; introduction to data-procedure encapsulation; dynamic allocation; linked structures; introduction to data structures - stacks and queues; time and space requirements.

Bibliography

[1] Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice Hall of India.

[2] E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill.

[3] Byron Gottfried, Schaum's Outline of Programming with C, McGraw-Hill.

MA 413L (Computer Programming Lab) Credit

(L-T-P) : 1 (0- 0- 1)

Familiarization of a computer and the environment and execution of sample programs, Expression evaluation, Conditionals and branching, Iteration, Functions, Recursion, Arrays, Data structures.
Any programming language like Java/C/C++/python may be used for programming.

Bibliography

[1] Brian W. Kernighan and Dennis M. Ritchie, The C Programming Language, Prentice Hall of India.

[2] E. Balaguruswamy, Programming in ANSI C, Tata McGraw-Hill.

[3] Seymour Lipschutz, Data Structures, Schaum's Outlines Series, Tata McGraw-Hill.

[4] Learning Python, 4th Edition, http://it-ebooks.info/go.php?id=304-1374920483-5d538867169f539241ca2c3e3f4c0089

[5] Some books of datastructure in various languages, http://www.brpreiss.com/books/opus5/

[6] Think Python, http://www.greenteapress.com/thinkpython/

[7] James Gosling, Bill Joy, Guy Steele, Gilad Bracha, The Java Language Specification, http://java.sun.com/docs/books/jls/

MA 404 (Abstract Algebra) Credit (L-T-P) : 4 (3- 1- 0)

Prerequisites: (Group, Subgroups, Normal subgroups, Lagrange's Theorem, Isomorphism Theorems)- Students must prepare themselves.
Class Equation, Sylow Theorems.
Ring Theory: Rings, Examples (Polynomial Rings, Gaussian Rings and matrix ring), Sub-ring, Ideals, Prime and Maximal Ideals, Rings of Fractions, Integral domains, Homomorphism of Rings and its basic theorems. Euclidean Domains, Principal Ideal Domains and Unique Factorizations, Gauss' Lemma, Irreducibility Criteria.
Field Theory: Field, Field extension, Algebraic extension, Splitting Field, Finite fields.

Bibliography

[1] I. Herrnstein, *Topics in Algebr*a, 2nd ed., John Wiley, 1999

[2] D. S. Dummit, R. M. Foote, *Abstract Algebra*, 3rd edition, Wiley India. 2014.

[3] Michael Artin, *Algebra*, Prentice Hall of India (1991).

[4] J. A. Gallian, *Contemporary Abstract Algebra*, Narosa.

MA 406 (Operations Research) Credit (L-T-P) : 4 (3-1- 0)

Formulation of LPP, Graphical Methods, Simplex method, Artificial methods, duality in linear programming, Integer Programming, Transportation Problem, Methods of initial solution, Test for optimality, Variations in transportation problem, Assignment problem, Hungarian method, Variations in assignment problem, Game Theory, Sequencing Problem, Processing n Jobs through two, three, and m machines, Critical Path Determination by CPM and PERT, Goal ProgrammingInventory control models.

Bibliography

[1] A. Ravindran, D. Phillips, and J. Solberg, *Operations Research: Principles and Practice*, 2nd Ed., Wiley India, 2007.

[2] H. A. Taha, *Operations Research: An Introduction*,Pearson Prentice Hall, 2004.

[3] J.C. Pant, *Introductio to optimization: Operations Research*, Jain Brothers, New Delhi, 2002.

MA 408 (Partial Differential Equations) Credit

(L-T-P) : 4 (3- 1- 0)

Formulation of P.D.E, First order P.D.E, Linear Equations of first order, Lagrange's Method, Monge strip, Charpit's method, Jacobi's method, Quasilinear equations, Non-linear first order P.D.E. Solution of a Cauchy problem, Solution of a characteristic Cauchy problem, Method of Characteristics, First order equation in morethan two independent variables: semilinear, quasilinear and non linear first order equations.
Fourier series, Fourier transforms and Integrals, separation of variables, heat equation, wave equation, Laplace equation, Transport equation.
Second order P.D.E: Classification and canonical forms, parabolic equation, hyperbolic equations, Elliptic equations, weak solutions, Lax-Milgram theorem, energy estimates, Laplace equation, Boundary Value Problems, Maximum principles, Uniqueness of solutions, Cauchy Problem, Harnacks theorem, Kelvin's Inversion theorem. Linear evolution equation, Duhamel's Principle.

Bibliography

[1] T. Amaranath, *An Elementary Course in Partial Differential Equations,* Narosa.

[2] W. E. Williams, *Partial Differential Equations,* Clarendon press Oxford.

[3] E. T. Copson, *Partial Differential Equations,* Cambridge University Press.

[4] I.N. Sneddon, *Elements of Partial Differential Equations,* Mc-Graw Hill .

[5] G. Evans, J. Blackledge, P. Yardley, *Analytic Methods for Partial Differential Equations*, Springer, 2000

[6] G. Evans, J. Blackledge, P. Yardley, *Numerical Methods for Partial Differential Equations* , Springer, 2000

MA 410 (Complex Analysis) Credit (L-T-P) : 4 (3- 1-0)

Complex plane, extended complex plane and its spherical representation Stereographic projection. Branch points, Limits and Continuity, differentiability of complex variable functions, Comparison between differentiability of real valued function and complex valued functions. Analytic functions, Necessary and Sufficient condition, The Cauchy-Riemann equations, Entire functions, Harmonic function and Harmonic conjugate function, Power series and radius of convergence of power series. Conformal Mapping, Cross ratio, Bilinear Transformation, Integration of complex-valued functions and differential forms along a piecewise differentiable path, Cauchy theorem, Cauchy integral formula, Morera's Theorem, Residues, Cauchy's Residue theorem, Evaluation of integrals by residue method, Taylor's expansion of holomorphic functions, Liouville's theorem, fundamental theorem of algebra, Maximum Modulus theorem; Schwarz' lemma, Laurents's expansion of a holomorphic function in an annulus, singularities of a function, argument principle, Rouche's Theorem.

Bibliography

[1] L. V. Ahlfors, *Complex Analysis* (Third Edition), McGraw-Hill (International Editions).

[2] J. B. Conway : *Functions of one complex variable*

[3] S. Lang, *Complex Analysis*, Springer.

[4] H. Silverman , *Complex Variables*.

[5] Moore, Haddock, *Complex Analysis*

MA 414 (Functional Analysis) Credit (L-T-P) : 4 (3-1- 0)

Metric spaces, Holders and Minkowskis inequalities, completeness compactness, Heine-Borel and Bolzano-Weierstrass Theorems in , Continuity, Uniform continuity of functions, Urysohn lemma, Tietze extension theorem, Normed spaces, Banach spaces, Riesz Lemma, Bounded linear operator, Ascoli theorem, Hahn-Banach theorem, Banach contraction mapping theorem, , Uniform boundedness principle, open mapping and closed graph theorems, weak convergence, Hilbert spaces, orthonormal sets, Riesz representation theorem, bounded linear operators on Hilbert spaces.
Text Book: B.V. Limaye: Functional Analysis, Revised 2nd edition, New Age International Limited, 1996.

Bibliography

[1] I. J. Maddox; Elements of Functional Analysis, Cambridge University Press.

[2] E. Kreyszig; Functional Analysis, John Wiley.

MA 503 (Mathematical Modeling and Simulation) Credit

(L-T-P) : 4 (3- 1- 0)

Introduction to mathematical modeling,Types of Modeling: Deterministic versus Stochastic, continuous versus discrete models. Modelling through ODE and PDE,System and System environment, Components of system, Type of systems, Type of models, Steps in simulation study, Advantages and Disadvantages of simulation. Limitations of simulation techniques, Comparison of simulation and analytical methods. Simulation of continuous systems, Simulation of discrete systems, Simulation of water reservoir system, Simulation of a servo system, simulation of an autopilot, Other examples of simulation, Monte- Carlo simulation, Real time simulation, Hybrid simulation, Cobweb model, Generation of random numbers, Test for randomness,Verification and Validation of simulation models, Case studies.

Bibliography

[1] J N Kapur, Mathematical Modelling, Wiely Eastern Ltd, New Delhi, 1988

[2] MA Pinsky, Partial Diffrential Equations and Boundary value problems with applications, 3rd Edition, McGraw Hill International, 1998

[3] Averill Law, W. David Kelton, .Simulation Modeling and Analysis., McGrawhill

[4] Geffery Gordon, .System Simulation., PHI.

MA 503L (Modelling and Simulation Lab) Credit

(L-T-P) : 2 (0- 0- 2)

Implementation of follwoing methods:
Solution of Ordinary Differential Equation - Linaear, Non linear, Volterra, Fredholm, Shooting Method, Adomian Decomposition Method Gaussian Qudrature, Chebyshev Functions etc.
Monto Carlo Simulation, Varios Simulation tool of MATLAB.
Introduction to Mathematica/Maple.

Bibliography

[1] M.K. Jain, S.R.K. Iyengar and R.K. Jain- Numerical Methods for Scientific and Enginering Computation, New age International publishers, Fourth Edition, 2003.

[2] Srimanta Pal- Numerical methods, Oxford University Press, Second edition, 2010.

MA 502 (Numerical methods for Partial Differential Equations) Credit (L-T-P) : 4 (3- 1- 0)

Finite difference methods for Parabolic, Elliptic and Hyperbolic equations.Dirichlet, Neumann and Mixed problems.Sparseness and the ADI method, Iterative methods for Laplace equation.Backward Euler, Crank-Nicolson schemes, Stability and convergence analysis, Lax's equivalence theorem. Method of characteristics, Lax-Wendroff explicit method, CFL conditions, Wendroff implicit approximation. Introduction to FEM/ADM.

Bibliography

[1] Joe D. Hoffman, Numerical methods for Engineers and Scientists, McGrow Hill.

[2] G. D. Smith, Numerical solutions to Partial Differential Equations, Brunel University, Clarendon Press, Oxford, 1985.

[3] C. Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method, Cambridge University Press, 1987.

[4] K. Eriksson et. al, Computational Differential Equations, Cambridge University Press, 1996.

[5] L. Lapidus and G. F. Pinder, Numerical Solution of Partial Differential Equations in Science and Engineering, John Wiley, 1982.

[6] H. P. Langtangen, Computational Partial Differential Equations Springer Verlag, 1999.

MA 504 (Topology) **Credit (L-T-P) : 3 (3- 0- 0)**

Topology of the real line R and plane R^2, Basic concepts of topological spaces, Continuous maps, Homeomorphism, Metric space, Properties of metric spaces, Connectedness and path connectedness, compactness and local compactness, Separation axioms, Hausdorff spaces, Normal spaces, Urysohn lemma, Tychonoff theorem, Complete Metric Spaces.

Bibliography

[1] J. R. Munkres, Topology, Pearson, 2000.

[2] C. Adams and R. Franzosa, Introduction to Topology: Pure and Applied, Pearson, 2000.

Part I

List of DSE-I: Discipline Specific Elective

MA 525 (Commutative Algebra) Credit (L-T-P) : 3 (3- 0- 0)

Ring and Ideal: Zero-divisors, Nilpotent Elements, Prime, Maximal Ideals, Nilradical, Jacobson radical, Extension and Contraction of ideals, Nakayama Lemma. Localization: Ring and Module of fractions, Spec of a ring. Integral Dependence: integral dependence, going-up and going-down theorems, Valuation Rings. Chain Conditions: Noetherian and Artin rings. Dimension Theory: Graded ring, Hilbert function and Samuel function, Dimension of Noetherian ring.

Bibliography

[1] M. F. Atiyah and I. G. Macdonald, *Introduction to Commutative Algebra*, Addison-Wesley, 1969

[2] H. Matsumura, *Commutative Ring theory*, Cambridge University Press, 1989.

[3] D. S. Dummit & R. M. Foote, *Abstract Algebra*, 2nd edition, John Wiley, 2008.

[4] S. Lang, *Algebra*, revised 3rd edition, Springer (2004).

MA 527 (Analytic Number Theory) Credit (L-T-P) :

3 (3- 0- 0)

Arithmetical Functions: Mobius, Euler totient functions and their relation, Mangoldt function, Dirichlet product, Dirichlet and Mobius inverse formulae, Multiplicative function, Inverse of Completely multiplicative function. Congruences: Residue classes and Complete residue classes, Euler-Fermat Theorem, Polynomial Congruences, Chinese remainder theorem and its applications. Quadratic residue and Quadratic Reciprocity law

Bibliography

[1] T. M. *Apostol, Introduction to Analytic number Theory*, Springer, 1980.

[2] J. P. Serre, *A course in Arithmetic*, Springer, 1973.

[3] J. Stillwell, *Elements of Number Theory*, Springer, 2003

MA 529 (Symmetries) Credit (L-T-P) : 3 (3- 0- 0)

Symmetry of plane figures, Group of motions of plane, Finite group of motions, Discrete group of motions, Abstract symmetries, Operation of cosets, Counting formula, Permutation representations, Finite subgroups of rotation group. Bilinear Form: Definition, Symmetric forms, Orthogonality, Geometry associated to positive form, Hermitian forms, Conic and Quadrics, Skew-symmetric forms.

Bibliography

[1] M. Artin, *Algebra*, Prentice Hall of India (1991).

[2] D. S. Dummit, R. M. Foote, *Abstract Algebra*, 2nd edition, John Wiley. 2008

Introduction, Kinematics of Fluid flow, Laws of fluid motion, Inviscid incompressible flows, two and three-dimensional motions, Lagrangian and Eulerian descriptions, inviscid compressible flows;
Viscous incompressible flows, Reynolds transport theorem, Navier-Stokes equations of motion and some exact solutions; Flows at small Reynolds numbers; Boundary layer theory.
Springer-Verlag, 1999.
Review of the governing equations of Incompressible viscous flows, Stream function: vorticity approach, artificial vorticity, transport equations, upwind differencing schemes, Primitive variables, Staggered grid, stability analysis, Dimensional analysis, pressure correction and vortex methods; Compressible inviscid flows, central schemes with combined and independent space time discretisation, Compressible viscous flows, Explicit, implicit and FTCS, BTCS methods; Grid generation: Structured and unstructured grid generation methods; Finite volume method: Finite volume method to convection-diffusion equations.

MA 531 (Number Theory and Cryptography) Credit

(L-T-P) : 3 (3- 0- 0)

Prime factorization prime numbers, Euclidean algorithm, the fundamental theorem of arithmetic, factorization methods, linear diophantine equations.Congruences linear congruences, Chinese remainder theorem, Wilson's, Fermat's and Euler's theorem, Euler's Phi-function. Applications to Congruences(time permitting) divisibility tests, hashing functions, public-key cryptography.Galios Field Theory.Complexity Theory: Design and analysis of algorithms.

Bibliography

[1] D. Welsh, *Codes and Cryptography*, Oxford, 2000.

[2] N. Koblitz, *A Course in Number Theory and Cryptography*, 2nd edition, Springer, 1994.

[3] J. Buchmann, *Introduction to Cryptography*, Springer, 2001.

MA 533 (Foundations of Cryptography) Credit

(L-T-P) : 3 (3- 0- 0)

Introduction, Perfect secrecy, One-time-pad encryption, Towards the computational approach: Indistinguishability-based definitions of secrecy, Concrete security and asymptotic security, Computational indistinguishability and computationally secure symmetric-encryption. Pseudo-random number generators (PRNG, or stream ciphers). The computational one-time pad. The cascading construction. Forward security for PRNGs. Pseudo-random functions (PRFs) and pseudo-random permutations (PRPs and strong PRPs/blockciphers). The Feistel transform and the design of DES. Applications of PRFs/s-PRPs: Chosen-Plaintext Attacks (CPA) security. *Modes of operation:* CTR, OFB, CFB, CBC. Data origin and Message Authentication Codes (MACs). Data integrity and cryptographic hash functions (collision resistant vs. universal hash functions).
Asymmetric cryptography: The key exchange problem. Merkle puzzles. The Diffie-Hellman Key Exchange protocol. Easy and hard problems in Z_p^*. Quadratic residuosity in Z_p^*. The Pohlig-Hellman cipher and Shamir's no-key protocol. *Public-key encryption:* Security notions and applications. ElGamal encryption. Easy and hard problems in Z_n^*. Quadratic residuosity in Z_n^*. Rabin encryption. The RSA family of permutations. Chosen-ciphertext (CCA) security. RSA-OAEP encryption. Hybrid encryption. Digital signatures and the notion of Public-Key Infrastructure.

Bibliography

[1] J. Katz and Y.a Lindell, *Introduction to Cryptography*, Springer, 2010

[2] O. Goldreich, *Foundations of Cryptography*, CRC Press (Low Priced Edition Available), Part 1 and Part 2.

[3] H. Delfs, H.t Knebl, *Introduction to Cryptography, Principles and Applications*, Springer Verlag.

[4] W. Mao, *Modern Cryptography, Theory and Practice*, Pearson Education (Low Priced Edition)

[5] S. Goldwasser and M. Bellare, *Lecture Notes on Cryptography*, Available in `http://citeseerx.ist.psu.edu`

MA 535 (Graph Theory) Credit (L-T-P) : 3 (3- 0- 0)

Graphs, Sub graphs, path and circuits, connected graphs, disconnected graphs and component, euler graphs, various operation on graphs, Hamiltonian paths and circuits, the traveling sales man problem. Trees and fundamental circuits, fundamental circuits, algorithms of primes, Kruskal and dijkstra Algorithms. Cuts sets and cut vertices, fundamental circuits and cut sets , connectivity and separability, network flows, planer graphs, Vector space of a graph and vectors, basis vector, cut set vector, circuit vector, circuit and cut set verses subspaces, orthogonal vectors and subspaces, incidence matrix of graph, sub matrices of A(G), circuit matrix, cut set matrix, path matrix and relationships among A, B, and C fundamental circuit matrix and rank of B, adjacency matrices, rank- nullity theorem . Coloring and covering and partitioning of a graph, Directed graphs, some type of directed graphs, Directed paths, and connectedness, Euler digraphs, trees with directed edges, fundamental circuits in digraph, matrices A, B and C of digraphs adjacency matrix of a digraph, counting of labeled and unlabeled trees, polyas theorem.

Bibliography

[1] N. Deo, *Graph Theory*, PHI.

[2] J. A. Bondy, U.S.R. Murthy, *Graph theory with application*, North Holland Publications, New York.

[3] R. Diestel,, *Graph Theoty*, Springer Verlag.

MA 537 (Differential Geometry) Credit (L-T-P) : 3 (3- 0- 0)

Geometry of curves, parameterization, arc length, curvature, torsion, serret frenet equation, global properties of curves in plane. Extrinsic geometry of surfaces, parameterization, tangent plane, differential, first and second fundamentals forms, curves in surface, normal and geodesic curvature of curves. Intrinsic geometry of surfaces, frames and frame fields, covariant derivatives and connection, Riemannian Metric, Gaussian curvature, Fundamental forms and the equations of gauss and coddazi-mainardi. Geometry of geodesics, Exponential map, geodesic polar coordinates, Fermi coordinates along a curve properties of geodesic, Jacobi fields, and convex neighbourhood. Global result from surfaces, The Gauss Bonnet Theorem, Hopf-Rinnoe theorem, cut points and conjugate points, the Bonnet-Myers theorem.

Bibliography

[1] M. D. Carmo, *Differential Geometry of curves and surfaces*, Prentice Hall.

[2] B. O'Niell, *Elementry Differential Geometry*, Academic Press.

[3] J. A. Thorpe, *Elementry Topics in Differential Geometry*, Springer.

MA 539 (Computational Mathematics with Python) Credit

(L-T-P) : 3 (3- 0- 2)

Elementary programing concepts: Arithmetic expressions, for-loops, logical expressions, if statements, functions and classes. These concepts are taught exclusively using mathematical/technical problems and examples. Mathematical Manipulations: Setting up matrices, solving linear problems, solving differential equations, finding roots, eigenvalues, resonances, without going into the mathematical details. More advanced concepts such as generators are presented and a basic introduction to the ideas of object oriented programming will be given.

Bibliography

[1] *Dive into Python*, Free available on Python website.

MA 541 (Mathematical Control Theory) Credit (L-T-P) : 3 (3- 0- 0)

Linear versus nonlinear systems: Nonlinear phenomena, multiple equilibria, limit cycles, complex dynamics, manifolds as state space, linearization methods for nonlinear systems, some classical examples. Planar dynamical systems: Phase plane techniques, limit cycles, Poincare-Bendixon theorem, multiple equilibria, index theory, bifurcations Mathematical preliminaries: Ordinary differential equations, control systems, solutions of initial value problems, existence and uniqueness of solutions, continuous dependence on initial conditions and parameters, differential equations with discontinuities, introduction to differential topology. Lyapunov stability: Definitions of stability, basic stability theorems, converse Lyapunov theorems, LaSalle Invariance Principle, exponential stability theorems, linear systems, feedback stabilization. Input-output stability: Definitions of input-output stability, small gain theorems, passivity, passivity theorems, describing functions, harmonic balance, connections with state space stability. Feedback linearization: SISO systems, input-output linearization, full state linearization, zero dynamics, applications to inversion, tracking and stabilization, MIMO systems, linearization by state feedback, full state linearization, dynamic extension, sliding mode, robust linearization. Geometric nonlinear control: Basics of differential geometry, tangent spaces, distributions and codistributions, Frobenius theorem, controllability concepts.

Bibliography

[1] H. K. Khalil. *Nonlinear Systems*. Prentice Hall, Englewood Cliffs, NJ, second edition, 1995.

[2] S. S. Sastry. *Nonlinear Systems*: Analysis, Stability and Control. Interdisciplinary Applied Mathematics, Springer Verlag, New York, 1999.

[3] H. Nijmijer and A. J. van der Schaft. *Nonlinear Dynamical Control Systems*. Springer Verlag, New York, 1990.

[4] A. Isidori. *Nonlinear Control Systems. Springer Verlag*, New York, third edition, 1995.

[5] E. D. Sontag. *Mathematical Control Theory: Deterministic Finite Dimensional Systems*, volume 6 of TAM, Springer Verlag, New York, second edition, 1998.

[6] F. Bullo, A. D. Lewis. *Geometric Control of Mechanical Systems*, volume 49 of Texts in Applied Mathematics, Springer Verlag, New York, 2004.

MA 543 (Dynamic Oceanography) Credit (L-T-P) : 3 (3- 0- 0)

Basic Hydrodynamic equations of motion and continuity, physical and chemical properties of ocean water, composition of sea water, salinity, density, thermal expansion of sea water, mass transport and free surface equation; The equation of motion in Oceanography, Reynolds Stresses, stability and double diffusion, steady motion in sea, Unsteady motions and their solutions, Currents without friction: Geostrophic flow, Currents with friction; wind driven circulation, Ekman Solution to the equation of motion with friction, Sverdrups solution for the wind driven solution, General Approach to numerical modeling of ocean circulation.

Bibliography

[1] Stephen Pond, and G. L. Pickard, *Introductory Dynamical Oceanography,*. Pergamon Press.

[2] G. L. Pickard and W.J. Emery, *Descriptive Physical Oceanography,*: Pergamon Press.

[3] J. Pedlosky, *Geophysical Fluid Dynamics,*. Springer Verlag.

Part II

List of DSE-II/DSE-III: Discipline Specific Elective

MA 522 (Applied Linear Algebra) Credit (L-T-P) : 3 (3- 0- 0)

Linear Algebra: Finite dimensional Vector spaces; basis and dimension; Linear transformations and their matrix representation; ; digonalization; invariant spaces and Canonical forms. Inner product space; Orthonormal basis, Projections, Gram-Schmidt process and $A = QR$, The geometry of linear equations, least squares approximation, eigen values and eigen vectors of e^{At}, Gershgorin circle theorem and its applications. Courant-Fischer minimax and related Theorems. Markov matrices, defective matrices, Jordan form, Generalized eigenvectors, Singular value decomposition, sparse matrices and Iterative methods.

APPLICATION OF LINEAR ALGEBRA: Linear Programming, Fourier Series, Computer graphics, Difference equations and powers A^k; Differential equations and e^{At}.

Bibliography

[1] G. Strang, *Linear Algebra and Its Applications*, 4th edition, Brooks/Cole (Cengage Learning), 2006

[2] G. Strang, *Introduction to Linear Algebra*, 4th edition, Cambridge University Press India Pvt Ltd, 2009

MA 524 (Algebra) Credit (L-T-P) : 3 (3- 0- 0)

F. Zulfeqarr and Amit K. Awasthi Review of Group Theory: Lagrange's theorem, Isomorphism theorems, Sylow theorems. Review of Ring theory: Ideals, ED, PID, UFD, Polynomial ring over field, Irreducibility Criteria. Review of Vector Space: Linear transformation, Linearly Independent/dependent vectors, Rank-nullity Theorem, Eigen values and Eigen vectors. Field Theory: Algebraic extension, Splitting fields, Separable and Inseparable extensions. Galois Theory: Galois extension, Fundamental theorem of Galois theory.

Bibliography

[1] D. S. Dummit, R. M. Foote, *Abstract Algebr*a, 2nd edition, john Wiley. 2008.

[2] J. B. Fralieigh, *A first course in abstract algebr*a, 5th ed., Addison-wesley, 1994.

[3] M. Artin, *Algebra*, Prentice Hall of India (1991).

[4] S. Lang, *Algebra*, 3rd edition, Springer (2004).

[5] I. N. Herstein, *Topics in Algebra*, 2nd ed., John Wiley, 1999.

MA 526 (Mathematical Modelling and Simulation)

Credit (L-T-P) : 3 (3- 0- 0)

Model and its different types, Finite models, Statistical models, Stochastic models, Formulation of a model, Laws and conservation principles, Discrete and continuous models, Evaluation of a model, Continuum model, Transport phenomena, Diffusion and air pollution models, Communication and Information technology, Monte Carlo Simulation, Randon number generation, Testing of randomness, Verification and validation of models, Real time simulation, Hybrid simulation, System dynamics, Case studies. (For implementation work - MATLAB)

Bibliography

[1] R. Aris, *Mathematical Modelling Techniques*, Dover, 1994.

[2] C. L. Dym and E. S. Ivey, Principles of Mathematical Modelling, Academic Press, 1980.

[3] M. S. Klamkin, *Mathematical Modelling: Classroom Notes in Applied Mathematics*, SIAM, 1986.

[4] A. Friedman and W. Littman, *Industrial Mathematics for Undergraduates*, SIAM, 1994.

[5] Y. C. Fung, *A First Course in Continuum Mechanics*, Prentice Hall, 1969.

[6] E. N. Lightfoot, *Transport Phenomenon and Living Systems*, Wiley, 1974.

MA 528 (Quantum Computing) Credit (L-T-P) : 3 (3-0- 0)

Mathematical foundations; quantum mechanical principles; quantum entanglement; reversible computation, qubits, quantum gates and registers; universal gates for quantum computing; quantum parallelism and simple quantum algorithms; quantum Fourier transforms and its applications, quantum search algorithms; elements of quantum automata and quantum complexity theory; introduction to quantum error correcting codes; entanglement assisted communication; elements of quantum information theory and quantum cryptography.

Bibliography

[1] M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press.

[2] J. Gruska, *Quantum Computing*, McGraw-Hill.

[3] *Lecture notes by John Preskill and N. D. Mermin* available in the Internet.

[4] L. Alamos, *MATLAB with Application*, Wiely.

MA 530 (Computational Number Theory) Credit

(L-T-P) : 3 (3- 0- 0)

Algorithms for integer arithmetic: Divisibility, gcd, modular arithmetic, modular exponentiation, Montgomery arithmetic, congruence, Chinese remainder theorem, Hensel lifting, orders and primitive roots, quadratic residues, integer and modular square roots, prime number theorem, continued fractions and rational approximations.
Representation of finite fields: Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials.
Algorithms for polynomials: Root-finding and factorization, Lenstra-Lenstra-Lovasz algorithm, polynomials over finite fields.
Elliptic curves: The elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm.
Primality testing algorithms: Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test.
Integer factoring algorithms: Trial division, Pollard rho method, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method.
Computing discrete logarithms over finite fields: Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm.

Bibliography

[1] V. Shoup, *A Computational Introduction to Number Theory and Algebra*, Cambridge University Press.

[2] A. J. Menezes, editor, *Applications of Finite Fields*, Kluwer Academic Publishers.

[3] J. H. Silverman and John Tate, *Rational Points on Elliptic Curves*, Springer International Edition.

[4] D. R. Hankerson, A. J. Menezes and S. A. Vanstone, *Guide to Elliptic Curve Cryptography*, Springer-Verlag.

[5] A. Das and C. E. Veni Madhavan, *Public-key Cryptography: Theory and practice*, Pearson Education Asia.

[6] H. Cohen, *A Course in Computational Algebraic Number Theory*, Springer-Verlag.

MA 532 (Advanced Optimization Techniques) Credit

(L-T-P) : 3 (3- 0- 0)

P. Saxena/D. Singh Generalized convex functions, Quasi convex functions, Quasi concave functions, Pseudo convex functions, Pseudo concave functions, Feasible direction, Cone of feasible direction, Necessary and Sufficient conditions, Fritz John Optimality conditions, Kuhn- Tucker optimality conditions, weak duality theorem, Saddle point optimality criteria, Generalized Gorden theorem, Lemkis Complementary Pivot algorithm, Linear Fractional Problem, Charnes-Cooper method, method of Gilmore and Gomory, Unconstrained optimization, method of steepest Descent, Newton-Raphson method, Conjugate direction method, Fletcher Reeves method, Davidon-Fletcher Powell Method, Constrained Optimization, Sequential unconstrained minimization technique, penalty and barrier function methods,

Bibliography

[1] D. G. Luenberger, Yinyu Ye, *Linear and nonlinear programming*,Springer, 2008.

[2] O. L. Mangasarian, *Nonlinear Programming*, McGraw Hill, 1969.

[3] M. S. Bazaraa, H. D. Sherali, C. M. Shetty, *Nonlinear Programming: Theory and Algorithms*, John Wiley and Sons, 2006.

MA 534 (Applied Approximation) Credit (L-T-P) :

3 (3- 0- 0)

A. Ujlayan Weierstrass Approximation theorem, Least square approximation, Minimax approximation, orthogonal polynomials, approximation with rational functions, Pade's approximation, Use of Pade's approximation. Various results related to existence of Adomian polynomials and its implementation in Matlab. Fundamental Adomian Decomposition method, various modified version of Adomian decomposition method, Applications of MADM to IVP, BVP.

Bibliography

[1] G. Adomian, *Nonlinear Stochastic system theory and Applications to physics*, Kluwer Academic Publishers, 1989.

[2] G. Adomian, *Nonlinear Linear stochastic operators equations* (1986). Academic Press, Inc (London)

[3] A. M Wazwaz, *Partial Differential equation and Solitary waves theory* (2009). Higher Education Press and Springer.

MA 536 (Fractional Calculus) Credit (L-T-P) : 3 (3-0- 0)

A. Ujlayan Gamma function, Mittag-Leffler function, Weight function, Grunwald Letnikov. Grnwald Letnikov Fractional Derivatives. Riemann-Liouville Fractional Derivatives. Some Other Approaches. Geometric and Physical Interpretation of Fractional Integration and Fractional Differentiation. Sequential Fractional Derivatives. Left and Right Fractional Derivatives. Properties of Fractional Derivatives. Laplace Transforms of Fractional Derivatives. Fourier Transforms of Fractional Derivatives. Mellin Transforms of Fractional Derivatives.Fractional Differential Equation of a General Form. Existence and Uniqueness Theorem as a Method of Solution. Dependence of a Solution on Initial Conditions. The Laplace Transform Method . Standard Fractional Differential Equations. Sequential Fractional Differential Equations. The Mellin Transform Method. Power Series Method. Babenko's Symbolic Calculus Method. Method of Orthogonal Polynomials. Numerical Evaluation of Fractional Derivatives. Approximation of Fractional Derivatives. The "Short-Memory" Principle. Calculation

Bibliography

[1] I. Podlubny, N. Heymans, *Physical interpretation of initial conditions for fractional differential equations with Riemann-Liouville fractional derivative*s. Rheologica Acta. vol. 45, 2006, pp. 765–771.

[2] I. Podlubny, I. Petras, B. M. Vinagre, P. O'Leary, L. Dorcak, *Analogue realizations of fractional-order controllers*. Nonlinear Dynamics, vol. 29, no. 14, 2002, pp. 281–296.

[3] I. Podlubny, *Geometric and physical interpretation of fractional integration and fractional differentiation*. Fractional Calculus and Applied Analysis, vol. 5, no. 4, 2002, pp. 367–386.

[4] I. Podlubny, *Matrix approach to discrete fractional calculu*s. Fractional Calculus and Applied Analysis, vol. 3, no. 4, 2000, pp. 359–386.

MA 538 (Scientific Computing) Credit (L-T-P) : 3 (3-0- 0)

A.K. Awasthi An introduction to Scientific Computing using Matlab/Octave covering the fundamental programming concepts (data types, abstraction, control structures, I/O, modules) and demonstrating the use of Matlab/Octave to solve scientific computing problems from a variety of disciplines including physics, chemistry, biology, computer science, and math. Topics to be covered include plotting, curve fitting, image processing, optimization, integration, differentiation, statistical analysis, ODE solving, and simulation. (In place of MATLAB free open source software FreeMAT may be used.)
Minor Project: Students will complete a minor project in which they demonstrate how matlab/octave can be used to solve a substantial scientific computing problem. They will write up their results using LaTeX, provide the matlab/octave code. (40% of Sessional Marks.)

Bibliography

[1] A. Gilat, *MATLAB: An Introduction with Applications*, 3rd edition, ISBN 978-0-470-10877-2.

[2] Online octave tutorials, `http://www.gnu.org/software/octave/doc/interpreter/`

MA 540 (Modern Cryptology) Credit (L-T-P) : 3 (3-0- 0)

A.K. Awasthi Mathematics of secure communications, secure communications and crypto-complexity, crypto-systems based on Knapsack problem, public key crypto-systems, algorithms for encryption and decryption, RSA systems, some applications of number theory and algebraic coding theory to cryptosystems. Recent advances in cryptology

Bibliography

[1] A. J. Menezes, Paul C. van Oorschot and Scott A. Vanstone, *Handbook of Applied Cryptography*, CRC Press ISBN: 0-8493-8523-7, 1996.

[2] W. Mao, *Modern Cryptography, Theory and Practice*, Pearson Education (Low Priced Edition)

MA 542 (Matrix Computation) Credit (L-T-P) : 3 (3-0- 0)

A.K. Awasthi Direct solution of linear systems : Gauss elimination, triangular decomposition, effects of round-off errors norms, condition numbers, inverses of perturbed matrices, accuracy of solution of linear systems, iterative refinements. Orthogonal triangularization. Eigenvalues and eigenvectors, similarity transformations, sensitivity of eigenvalues and eigenvectors, singular value decomposition. The Q-R algorithm, Hessenberg and triangular forms, the power and inverse power methods. Explicitly and implicitly shifted Q-R algorithms, computing singular values and vectors. The generalized eigenvalue problem. Sparse systems.

Bibliography

[1] D. S. Watkins, *Fundamentals of Matrix Computations*, Wiley Interscience, 2002.

MA 544 (Numerical Optimization) Credit (L-T-P) : 3 (3- 0- 0)

A.K. Awasthi Algorithms and complexity, the classes P and NP. NP complete problems. Simplex method for linear programming and its computational complexity: Karmarkars projective scaling algorithm. Unconstrained optimization: basic descent methods, conjugate direction methods and quasi-Newton methods. Constrained optimization: primal methods, penalty and barrier methods, cutting plane and dual methods. Parallel algorithms for numerical optimization. Optimization and Neural Networks.

Bibliography

[1] J. NocedalJ, S. J. Wright, *Numerical Optimization*, 2^nd Edition, Springer, 2000.

MA 546 (Analysis of Algorithms) Credit (L-T-P) : 3 (3- 0- 0)

A.K. Awasthi

Mathematical Foundations: Growth of Functions, Summations and Recurrences, Sets, Relations, Functions, Graphs, and Trees, Counting and Probability Sorting and Order Statistics: Heapsort, Quicksort, Lower Bounds for Sorting, Sorting in Linear time, Medians and Order Statistics Data Structures: Stacks, lists, queues, and pointers, Hashing, Binary Search Trees, Red-Black Trees, Design and Analysis Techniques: Dynamic Programming, Greedy Algorithms, Amortized Analysis, More Data Structures: B-Trees, Binomial and Fibonacci Heaps, Disjoint-Set Union Graph Algorithms: Basic Graph Algorthms, Spanning Trees, Shortest Path Algorithms, Max Flow Selected Topics: Matrix Operations, Number-Theoretic Algorithms, String Matching, NP Complete Problems, Approximation Algorithms, Parallel Algorithms,

Bibliography

[1] T. H. Cormen, C. E. Leiserson and R. L. Rivest *Introduction to Algorithms*, MIT Press, 1990.

[2] A. V. Aho, J. E. Hopcroft, J. D. Ullman, *Data Structures and Algorithms*, Addison-Wesley.

[3] M. Garey, D. Johnson, *Computers and Intractability: A Guide to the Theory of NP-Completeness*, Freeman.

[4] A. Gibbons, *Algorithmic Graph Theory*, CUP.

[5] D. Knuth, *The Art of Computer Programming: Vol. 3: Sorting and Searching*, Addison-Wesley.

[6] R. Sedgewick *Algorithms*, Addison-Wesley.

MA 548 (Stochastic Process and Modeling) Credit

(L-T-P) : 3 (3- 0- 0)

Anjana Solanki
Markov Process and Markov Chain, Transition Probabilities Matrix, Multi Period transition Probabilities,Steady-State conditions, Birth and death Process, Steady State Solution , Pure Birth Process , Pure death Process, Special cases of Birth and death Process, Poisson Random Process, Probability Law for Poisson Process, Mean and Variance of Poisson Process, Bernoulli Process, Stochastic Process, Characteristics of a Markov Chain, State & Transition Probabilities, Multi-Period Transition Probabilities, Poisson Random Process, Probability Law for Poisson Process, Birth & Death Process, Structure, Performance measures & Probability distribution of Queuing models, Single Server & Multi Server Queuing models, Multi- Phase Service Queuing models. Vacational & Priority Queuing models. Non Markovian Queues and Queues Network.

Bibliography

[1] J.K. Sharma, *Operations Research: Theory and Applications*, Macmillan Publication

[2] D. Gross, J. F. Shortle, J. M. Thompson, C. M. Harris, *Fundamentals of Queueing Theory*, John Wiley, 2008

[3] R. Nelson, Probability, *Stochastic Process and Queueing theory,* Springer, New York.

[4] M. L. Chaudhary, J. C. G. Templeton, *First course of Bulk Queueing models*, John Wiley, 1983

MA 550 (Supply Chain Inventory Models) Credit

(L-T-P) : 3 (3- 0- 0)

Anjana Solanki
Supply Chain Inventory Models Introduction of Deterministic and Probabilistic Inventory Control Models, Factors involved in inventory Problem Analysis, Inventory Model Building, Single Item Inventory Control Models without Shortages, Single item Inventory Control Models with Shortages, Multi-Item Inventory Models with Constraints, Single Item Inventory Controls Model with Quantity Discount, Inventory Control Models with Uncertain Demand, Information Systems for Inventory Control, Instantaneous Demand Inventory Control Models without Set-up Cost, Continuous Demand Inventory Control Models without Set-up Cost, Instantaneous Demand Inventory Control Models with Set-up Cost.

Bibliography

[1] J.K. Sharma, *Operations Research: Theory and Applications*, Macmillan Publication

[2] E. Naddor, *Inventory Systems*, Wiley Publication

MA 552 (Perturbation Methods) Credit (L-T-P) :

3 (3- 0- 0)

Sushil Kumar Asymptotic expansion and approximations, Asymptotic solution of algebraic and transcendental equations, Introduction to the asymptotic solution of differential equations. Singular and Regular Perturbations, Perturbed second order differential equations, Dimensional analysis, Initial and boundary value problems, Partial differential equations, Error estimation. Multiple scales, Overview of multiple scales and averaging, The first order two-scale approximation, Higher order approximations. Methods of WKB type, Introductory examples, The formal WKB expansion without turning points, Ray methods

Bibliography

[1] J. A. Murdock, *Perturbations Theory and Methods*, John Wiley and Sons, 1991.

[2] M. H. Holmes, *Introduction to Perturbation Methods*, Springer Verlag, 1995.

[3] A. H. Nayfeh, *Perturbation Methods*, John Wiley and Sons, 2000.

MA 554 (Finite Element Methods for Partial Differential Equations) Credit (L-T-P) : 3 (3- 0- 0)

Sushil Kumar
Basic concepts of finite element methods; Elements of function spaces, Lax-Milgram theorem, piecewise polynomial approximation in function spaces, Construction of finite element spaces. Polynomial approximations and interpolation errors. Convergence analysis: Galerkin orthogonality and Ceas lemma, Bramble-Hilbert lemma, Aubin-Nitsche duality argument; Applications to elliptic, parabolic and hyperbolic equations, a priori error estimates, variational crimes; A posteriori error analysis reliability, efficiency and adaptivity. Computational experiments using MATLAB.

Bibliography

[1] P. G. Ciarlet, *The Finite Element Method for Elliptic Problems*, North-Holland, 1978.

[2] J. N. Reddy, *An Introduction to Finite Element Method*, McGraw Hill, 1993.

[3] S. C. Brenner, L. R. Scott, T*he Mathematical Theory of Finite Element Methods*, 2nd edition, Springer, 2002.

[4] Z. Chen, *Finite Element Methods and Their Applications*, Springer, 2005.

[5] D. L. Logan, *A First Course in the Finite Element Method*, 4th edition, Cenegage Learning, 2007.

[6] A. J. Davies, *The Finite Element Method: An Introduction with Partial Differential Equations*, Oxford University Press, 2011.

Finite Difference Approximations in two and three space dimensions, Solution of linear/Non-linear parabolic equations: Reduction of system of ordinary differential equations, Pade's Approximants, Gerschogorin,s circle theorem, Newton's linearization method, Richtmyer's linearization method, Stability of Multistep Schemes, Leapfrog scheme, Dissipation, Dispersion, Analysis of Well-Posed and stable problems, stability Methods for solving Elliptic Equations, Method of Steepest Descent and the Conjugate-Gradient Method, hyperbolic equations: Lax-Wendroff explicit method for a set of simulataneous equations, Finite element method for ordinary differential equations, Finite Element Approximations in One/two space dimensions, Boundary integral equation methods. Lab Work: Implementation of various methods with MATLAB/Python/C++.

MA 556 (Integral Equations and Integral Transform)

Credit (L-T-P) : 3 (3- 0- 0)

S. Kumar Introducation and formulation of integral equation, Classification Integral Equations (Fredholm, Volterra, Integro-Differential Equations, Singular Integral Equations, Genralized Abel Integral Equation, Weakly-singular Volterra Equations). Converting Volterra Equation to ODE, Conversion of IVP(ODE) to Volterra equation, Conversion of BVP(ODE) to Fredholm equation.
Existence and uniqueness of solutions using fixed-point theorems in case of Linear and nonliner Volterra and Fredholm integral equations. Pade's Approximant Z-Transform, Mellin Transform, Laplace transform, definition, properties and evaluation of transforms, Convolution theorem for Z - transforms, Applications to integral equations. Laplace transform method for Partial differential equation.
Adomian Decomposion method, and Modified Adomian decomposition method Direct Computation method, successive approximation method, Comarison between alternative methods. For linear/nonlinear integral equation, Integral-Differential Equations, Singular Integral Equations Abel's problem.

Bibliography

[1] A.M. Wazwaz, *A First course in integral equations* (1997) (world Scientific)

[2] A. J. Jerri, *Introduction to Integral Equation with Applications*, 2nd edition, Wiley Interscience, (1999).

[3] L. Debnath, D. Bhatta, *Integral transforms and their applications*, 2nd ed, Chapman& Hall/CRC, 2007

MA 558 (Measure and Integration) Credit (L-T-P) :

3 (3- 0- 0)

S. Kumar Review of Riemann Integral, Riemann-Stieltjes Integral. Lebesgue Measure; Lebesgue Outer Measure; Lebesgue Measurable Sets. Measure on an arbitrary sigma -Algebra; Measurable Functions; Integral of a Simple Measurable Function; Integral of Positive Measurable Functions.
Lebesgue's Monotone Convergence Theorem; Integrability; Dominated Convergence Theorem; Lp - Spaces. Differentiation and Fundamental theorem for Lebesgue integration.
Product measure; Statement of Fubini's theorem.

Bibliography

[1] G. D. Barra, *Measure and Integration*, Wiley Eastern, 1981.

[2] H. L. Royden, *Real Analysis*, Third edition, Prentice-Hall of India, 1995.(Chapter 3, Sections 1-5)

[3] W. Rudin, *Real and Complex Analysis*, Third edition, McGraw-Hill,International Editions, 1987. (Chapters 1, 3)

[4] I. K. Rana, *An Introduction to Measure and Integration*, Second Edition, Narosa, 2005.

[5] D. L. Cohn, *Measure Theory* , Birkhauser, 1997.

[6] P.K. Jain, V.P. Gupta, *Lebesgue Measure and Integration*, New Age International, 2006.

MA 560 (Dynamic Meteorology) Credit (L-T-P) :

3 (3- 0- 0)

S. Kumar Basic Concepts, hydrostatic equilibrium, hydrostatic stability and convection, mean annual heat balance, fundamental forces, equations of motion in rotating and non rotating coordinate frames, scale analysis, basic conservation laws, spherical coordinates, geostrophic approximation, hydrostatic balance, static stability, circulation and vorticity conservation of potential vorticity, Rossby adjustment theory, quasi-geostrophic equations, omega equations, hydrodynamic instability.

Bibliography

[1] 1. James, C. Holton, *An Introduction to Dynamic Meteorology,*, Academic Press, 3rd edition.

[2] 2. S. L. Hess, *Introduction to Theoretical Meteorology,*, Krieger Pub. Co. Press.

MA 562 (Advanced course in ODE and PDE) Credit

(L-T-P) : 3 (3- 0- 0)

Existence and uniqueness of solutions to first order equations: Picards Theorem, Lipchitz's condition, Gronwell's inequality, Qualitative properties of the solutions of second order ODE, Stability, Lyapunov's direct method, Fundamental matrix solutions. Classification of second order P.D.E. Solution of P.D.E (Wave and Heat Equation) by Duhamel's Principle, Maximum and minimum principles.

Bibliography

[1] M. Braun: *Differential Equations and Their Applications : An Introduction to Applied Mathematics* (Texts in Applied Mathematics, Vol. 11)(Springer)

[2] MA Pinsky, Partial Differential Equations and Boundary value problems with applications, 3rd Edition, McGraw Hill International, 1998.

[3] G.F. Simmons, Differential equations with applications and Historical Notes, Second Edition, McGraw Hill, 1991

[4] T. Amarnath : An Elementary Course in Partial differential Equations, Narosa.

MA 564 (Discrete Mathematics) Credit (L-T-P) : 4 (3-1- 0)

Propositional logic: Syntax, semantics, valid, satisfiable and unsatisfiable formulas, encoding and examining the validity of some logical arguments. Proof techniques: forward proof, proof by contradiction, contrapositive proofs, proof of necessity and sufficiency. Sets, relations and functions: Operations on sets, relations and functions, binary relations, partial ordering relations, equivalence relations, principles of mathematical induction. Size of a set: Finite and infinite sets, countable and uncountable sets, Cantor's diagonal argument and the power set theorem, Schroeder-Bernstein theorem. Introduction to counting: Basic counting techniques - inclusion and exclusion, pigeon-hole principle, permutation, combination, summations. Introduction to recurrence relation and generating function. Algebraic structures and morphisms: Algebraic structures with one binary operation- semigroups, monoids and groups, congruence relation and quotient structures. Free and cyclic monoids and groups, permutation groups, substructures, normal subgroups. Algebraic structures with two binary operations - rings, integral domains and fields. Boolean algebra and Boolean ring. Introduction to graphs: Graphs and their basic properties - degree, path, cycle, subgraphs, isomorphism, Eulerian and Hamiltonian walks, graph coloring, planar graphs, trees.

Propositions and Logical Operations, Conditional Statements, methods of Proof, mathematical Induction, principle of Inclusion and Exclusion, Counting, Permutation, Combination, Pigeonhole principle, Recurrence Relations, Closures of relations, Generating Functions, Divide and Conquer Algorithms, Relation and Digraphs, properties of Relations, equivalence relations, Transitive Closure and Warshall's Algorithms, functions, order relation and structure, partially ordered sets, Lattices, Finite Boolean Algebra, functions on Boolean Algebra, Logic Gates, Trees, Tree searching, minimal Spanning trees, Graphs, Euler Paths and Circuits, Hamiltonian Paths and Circuits, shortest path problems, Transport network .

Bibliography

[1] K. H. Rosen, *Discrete Mathematics and its Applications*, Tata McGraw-Hill.

[2] C. L. Liu, *Elements of Discrete Mathematics*, Tata McGraw-Hill.

[3] N. L. Biggs, *Discrete Mathematics*, Oxford University Press.

[4] K. Bogart, C. Stein and R. L. Drysdale, *Discrete Mathematics for Computer Science*, Key College Publishing.

[5] T. Koshy, *Discrete Mathematics with Applications*, Elsevier.

[6] R. P. Grimaldi, *Discrete and Combinatorial Mathematics*, Pearson Education, Asia.

[7] B. Kolman, R. Busby and S. C. Ross, N. Rehman, *Discrete Mathematical Structures*, Pearson Prentice Hall.