

Proposed Updated Course Structure for M.Sc. in Applied Mathematics *(Applicable since session 2018-2019)*

12th Board of Studies
(held on 24-08-2018)



Department of Applied Mathematics
School of Vocational Studies and Applied Sciences
Gautam Buddha University
Greater Noida, UP-201312

Preamble

The Program M.Sc. in Applied Mathematics was started in 2012 since the inception of the Department of Applied Mathematics. The progression of students belonging to this course is excellent.

In the development of this course, we considered various stakeholders e.g. students, faculty, industry feedback etc. To make course more applied we have added new modules of laboratory work. The laboratory works certainly improve the skills of our students. This program has duration of 2 years and in this duration, students will earn 90 credits to get his M.Sc. degree.

Minimum Eligibility criteria for admission:

Candidates should have either one of the following degrees:

1. Bachelor of Science in Mathematics under the 10+2+3/4 system with at least 55% marks or equivalent
2. B.Tech. or B.E. (in any engineering branch) with at least 6 out of 10 CGPA or equivalent.

For SC/ST and PWD candidates the qualifying degree is relaxed to 50% (or 5.5 CGPA out of 10)

Selection Procedure

Candidates will be selected on the basis of GBU admission policy.

Evaluation of Courses:

The marks distribution of the courses having lab component will be as follows:

Theory Examination	50 Marks
Practical Examination	50 Marks

The marks distribution of the courses without lab component will be as follows:

Theory Examination	70 Marks
Internal Assessment	25 Marks (Quiz, Assignments, Presentation or/and oral examination)
Attendance	05 Marks

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Program Structure

Semester I

S. No.	Course Code	Course	Category	Hours			Credit
				L	T	P	
1	MA-401	Linear Algebra	C	4	1	0	5
2	MA-403	Abstract Algebra	C	4	1	0	5
3	MA-405	Real Analysis	C	4	1	0	5
4	MA-407	Ordinary Differential Equations	C	4	0	2	5
5	MA-409	Number Theory and Cryptography	C	3	0	4	5
Total of Semester Credits							25

Semester II

S.No.	Course Code	Course	Category	L	T	P	Credit
1	MA-404	Topology	C	4	1	0	5
2	MA-406	Operations Research	C	4	1	0	5
3	MA-408	Partial Differential Equations	C	4	1	0	5
4	MA-410	Complex analysis	C	4	1	0	5
5	MA-412	Measure and Integration	C	4	1	0	5
Total of Semester Credits							25

Semester III

S.No.	Course Code	Course	Category	L	T	P	Credit
1	Any course of credit 4 from other departments.		GE	-	-	-	4
2	MA-501	Functional Analysis	C	4	1	0	5
3	MA-503	Integral Equations and Calculus of Variations	C	4	1	0	5
4	MA-xxx	DSE-I	DSE	3	0	0	3
5	MA-xxx	DSE-II	DSE	3	0	0	3
Total of Semester Credits							20

Semester IV

S.No.	Course Code	Course	Category	L	T	P	Credit
1	MA-502	Mathematical Statistics with R	SE	4	0	2	5
	MA-504	Evolutionary Algorithms	SE	4	0	2	5
	MA-506	Numerical Solution of ODE and PDE with MATLAB	SE	4	0	2	5
	MA-508	Information Theory and Coding Theory	SE	4	0	2	5
Total of Semester Credits							20
Overall Credits							90

OR

S.No.	Course Code	Course	Category	L	T	P	Credit
1	MA-520	Project	Project				10
	-	Choose any two subjects from (MA-502, MA-504, MA-506, MA-508)	SE				10
Total of Semester Credits							
Overall Credits							90

Abbreviation: C: Core Course, SE: Specialization Electives, SEC: Skill Enhancement Course, DSE: Discipline Specific Elective, GE: Generic Elective, L-lecture, T-Tutorial, P-Practical.

Note: Tutorial batches will contain maximum thirty students and the size of the practical group for practical papers is recommended to be 12-15 students. Concerned departments can add/delete some experiments of similar nature in the Laboratory papers.

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

S. No.	Course Code	Course
1	MA 001	Machine Learning for Data Science
2	MA 002	Graph Theory
3	MA 003	Differential Geometry
4	MA 004	Optimization Techniques
5	MA 005	Elliptic Curves
6.	MA 006	Discrete Mathematics
7.	MA 007	Fractional Calculus
8.	MA 008	Applied Linear Algebra
9.	MA 009	Commutative Algebra
10.	MA 010	Fuzzy theory and applications
11.	MA 011	Design Optimization
12.	MA 012	Computational Mathematics with Python
13.	MA 013	Optimal Control to PDEs
14.	MA 014	Advanced Optimization Techniques
15.	MA 015	Applied Approximation
16.	MA 016	Perturbation Methods
17.	MA 017	Dynamic Meteorology
18.	MA 018	Coding Theory
19.	MA 019	Analytic Number Theory
20.	MA 020	Symmetries
21.	MA 021	Numerical Analysis with Programming
22	MA 022	Dynamic Oceanography
23.	MA 023	Foundations of Cryptography
24.	MA 024	Quantum Computing
25.	MA 025	Computational Number Theory
26.	MA 026	Queuing Theory & Stochastic Process
27.	MA 027	Sampling Theory & Statistical Inference
28.	MA 028	Mathematical modeling with MATLAB
29.	MA 029	Methods of Applied Mathematics
30.	MA 030	Finite Element Methods for Partial Differential Equations
31.	MA 031	Fluid Mechanics
32.	MA 032	Computational Fluid Dynamics

Note: New courses can be added to the list of DSE and SE with the permission of the department BOS (local body only). One expert advice may be taken through email to include any particular course.

Detailed Syllabus

First Semester

MA 401 (Linear Algebra)

Credits (L-T-P): 5(4- 1- 0)

Prerequisite: Algebra on Matrices, Elementary Matrices and their properties, Application to System of linear equations, Rank of a matrix.

Vector Spaces over field F , Subspaces, Bases and Dimension, Some infinite-dimensional vector spaces, Linear maps and their matrix representation, Algebra of linear maps, Isomorphism, Lineal functional, Dual spaces, Double dual, Annihilator, Transpose of a linear map, Inner product spaces, Cauchy-Schwarz inequality, Orthogonality, Orthonormal bases, Gram-Schmidt Orthonormal process, Complex inner product spaces, Polynomial of matrices, Eigen-value and Eigen-vectors, Diagonalization of matrices, Invariant subspaces, Direct sum decomposition, Invariant direct sums, The primary decomposition theorem, Jordan canonical form, cyclic subspaces, Rational canonical form, Quotient spaces, Bilinear form, Positive definite, Symmetric form, Hermitian form.

Supplementary Topics: Modules, Tensor product, Rigid motions.

Text Book

K. Hoffman and R. Kunze, Linear Algebra. Prentice Hall of India.

Reference Books

- [1] S. H. Friedberg, Arnold J Insel and Lawrence Spence, Linear Algebra, 4th ed., Pearson Education
- [2] S. Lipschutz and M. Lipson, *Linear Algebra*, Schum's series, McGraw Hill Education. 2005
- [3] M. Artin, *Algebra*, PHI Learning Private Limited 2005.

MA-403 (Abstract Algebra)

Credits (L-T-P): 5(4- 1- 0)

Prerequisite: Basic group theory. Examples of Dihedral, symmetric, permutation, Quaternion and matrix groups: GL_n, SL_n etc.

Isomorphism theorems, Cayley Theorem, Class equation, Sylow theorems. Rings Theory: Definitions with some standard examples, Basic properties, Types of rings, Matrix rings, Ideals, Prime and Maximal ideals, Quotient rings, Homomorphisms of rings, Field of fractions, Polynomial ring with some properties, Polynomial functions, symmetric polynomials, Gaussian rings, Principal ideal domains, Euclidean domains, Unique factorization domains, Gauss' lemma, Irreducibility criterion. Field Extension: Basic theory of field extensions, Algebraic extensions, Splitting field of a polynomial, Algebraic closure, Separable and inseparable extensions, Group of automorphisms, Galois group (Introduction).

Supplementary Topics: Classification of groups of small orders up to 15. Classification of finitely generated abelian groups.

Text Book

N. Jacobson, Basic Algebra-I, 2nd Edition, Dover Publication 2009.

References Books

- [1] D. S. Dummit, R. M. Foote, Abstract Algebra, 3rd edition, Wiley India. 2014.
- [2] J. B. Fraleigh, A first course in abstract algebra, Pearson, 1994.
- [3] Michael Artin, Algebra, Prentice Hall of India (1991).
- [4] Serge Lang, Algebra, revised 3rd edition, Springer (2004).
- [5] J. A. Gallian, Contemporary Abstract Algebra, Narosa.

MA 405 (Real Analysis)**Credits (L-T-P): 5(4- 1- 0)****Prerequisite:** Basic real analysis and linear Algebra.

Construction of Real Number System; Dedekind's cut; Topology on \mathbb{R} , Weierstrass Theorem, Heine-Borel Theorem, Connectedness, Definition and existence of Riemann Stieltjes integral, Properties of the integral, Integration and Differentiation, Rectifiable curves, Sequence and series of functions: Point-wise and uniform convergence, Cauchy criterion for uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Equicontinuous families of functions, Arzela-Ascoli theorem, Stone-Weierstrass theorem, Special functions: Power series, Fourier series, Gamma functions, Calculus of several variables: Contraction principle, Inverse function theorem, Implicit function theorem, rank theorem, differentiation of integrals.

Supplementary Topics: Integration of differential forms: Stoke's theorem close and exact form.**Text Book****W. Rudin, Principles of Mathematical Analysis, McGrawHill****References Books**

- [1] T. Apostol, Mathematical Analysis, Addison-Wesley.
- [2] H. L. Royden, Real Analysis, Macmillan Publishing Compa
- [3] S. Lang - Analysis.

MA 407 (Ordinary Differential Equations)**Credits (L-T-P): 5(4- 1- 0)****Prerequisite:** Basic knowledge of calculus, linear Algebra and complex number system.

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 theorem sand 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, Nonhomogeneous Boundary Value Problems, Green's functions.

Supplementary Topics: System of ODE-Linear homogeneous system, Fundamental matrix, exponential of the matrix, Phase space, Nonlinear system, introduction of system analysis.**Text Book****W. E. Boyce and R. C. Di Prima, Elementary Differential Equations and Boundary Value Problems, Wiley, 2000.****References Books**

- [1] G. F. Simmons, Differential equations with applications and Historical Notes, Second Edition, Mc-Graw 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. Di Prima, 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 (Number Theory and Cryptography)**Credits (L-T-P): 6(3- 0- 4)****Prerequisite:** Basic knowledge number theory.

Notion of Complexity Theory, 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. Classical Cryptosystems, Crypt analysis, Perfect Secrecy, Stream Ciphers, Block Ciphers, Hash Functions, Public-key cryptography: RSA, Implementation of RSA, Primality Testing, Factoring Algorithm. Discrete logarithmic Algorithms. Diffie Hellman Problem. Finite Field.

Supplementary Topics: DES, Zero knowledge protocol, Threshold cryptosystems, Practical aspects of Cryptography**Text Book****N. Koblitz, A Course in Number Theory and Cryptography, 2nd edition, Springer, 1994****References Books**

- [1] D. Welsh, Codes and Cryptography, Oxford, 2000.
- [2] J. Buchmann, Introduction to Cryptography, Springer
- [3] Joseph H. Silverman, A Friendly Introduction to Number Theory, Pearson, 2013

Second Semester**MA 404(Topology)****Credits (L-T-P): 5(4- 1- 0)****Prerequisite:** Basic sets theory, Cartesian Products, Relations, Finite Sets, Countable and uncountable sets, Infinite Sets and the Axiom of Choice, Well ordering, Zorn's Lemma and their equivalence..

Metric Spaces, Neighbourhoods and Continuity, Topological spaces, Basis for a topology, Order topology, Product topology, Subspace topology, Closed sets, Limit points, Continuous functions, Homeomorphism, Quotient topology, Metric topology, Connected spaces, Components, Compact spaces, Local compactness, Path-connected spaces, Path-connected components, Countability axioms, Separation axioms, Hausdorff spaces, Normal spaces, Regular spaces, Urysohn lemma, Urysohn metrization theorem, Tietze extension theorem, Tychonoff theorem. One-point compactification, Stone Cech compactification.

Supplementary Topics: Topological Groups, Nets**Text Book****J. R. Munkres, Topology, 2nd ed., Pearson, 2006****References Books**

- [1] S. Willard, *General Topology*, Addison – Wesley.
- [2] C. Adams and R. Franzosa, Introduction to Topology: Pure and Applied, Pearson, 2000.

MA 406 (Operations Research)**Credits (L-T-P): 5(4- 1- 0)****Prerequisite:** Linear Algebra.

Basics of Linear Programming Problem, Convex sets and their properties, Duality in linear programming, Complementary slackness theorem, Game Theory, Linear programming and matrix game equivalence, Sequencing Problem, Processing n Jobs through two, three, and machines, Replacement Problems, Deterioration with time, cost

increasing with time, money value into consideration, Critical Path Determination by CPM and PERT, Goal Programming Inventory control models, Dynamic Programming.

Supplementary Topics: Sensitivity Analysis of LPP, Transportation problem.

Text Book

J.C. Pant, Introduction to optimization: Operations Research, Jain Brothers, New Delhi, 2002.

References Books

- [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.

MA 408 (Partial Differential Equations)

Credits (L-T-P): 5(4- 1- 0)

Prerequisite: Calculus, Linear Algebra and ODE.

Introduction, Classification to first order PDEs, Mathematical models leading to PDEs, Method of Characteristics, Scalar conservation laws and linear transport equation, Traffic dynamics, The Rankine-Hugoniot condition, The entropy condition, The Riemann problem, The Cauchy problem, Classification of second order equations: canonical forms of Hyperbolic, Parabolic, elliptic equations. One dimensional wave equation and De'Alembert's method, Domain of dependence and region of influence, The Cauchy problem for the non homogeneous wave equation, Methods of separation of variables for heat, Laplace and wave equations, The energy method and uniqueness, Sturm–Liouville problems and eigen function expansions, Elliptic equations: maximum principle, applications of the maximum principle, Green's identities, The maximum principle for the heat equation, Poisson's formula, Laplace equation: mean value property, weak and strong maximum principles, Green's function, Poisson's formula, Dirichlet's principle, Harnack's inequality and Liouville's theorem.

Text Book

Y. Pinchover and J. Rubinstien, Introduction to Partial Differential Equations, Cambridge University Press.

References Books

- [1] Sadro Salsa, Partial Differential Equations in action, Springer-verlag Italia, Milano 2008.
- [2] L.C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, Vol. 19, American Mathematical Society, 1998.
- [3] Walter A Strauss, Partial Differential Equations,
- [4] I.N. Sneddon, Elements of Partial Differential Equations, Mc-Graw Hill .

MA 410 (Complex Analysis)

Credits (L-T-P): 5(4 - 1- 0)

Prerequisite: Basic real analysis, complex number system, Complex plane.

Limits, Continuity, and 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, Laurent's expansion of a holomorphic function in an annulus, singularities of a function, argument principle, Rouché's Theorem.

Supplementary Topics: Stereographic projection, branch points, elementary functions: polynomial, rational, exponential and hyperbolic functions.

Text Book

H. Silverman, Complex Variables.

References Books

- [1] L. V. Ahlfors, Complex Analysis (Third Edition), McGraw-Hill (International Editions).
- [2] J. B. Conway : Functions of one complex variable
- [3] Brown and Churchill, Complex Analysis, McGraw Hill.
- [4] Moore, Haddock, Complex Analysis

MA 412 (Measure and Integration)

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

Prerequisite: Review of Riemann Integral, Riemann-Stieltjes Integral.

Outer Measures, Carathodory Extension, 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; L^p -Spaces. Absolute Continuous Function on \mathbb{R} , Differentiation and Fundamental theorem for Lebesgue integration. Measure on Product Spaces; Fubini's theorem.

Supplementary Topics: Complex measures, Radon-Nikodym theorem.

Text Book: G. D. Barra, Measure and Integration, Wiley Eastern, 1981

References Books

- [1] G. D. Barra, Measure and Integration, Wiley Eastern, 1981.
- [2] Terence Tao, An Introduction to Measure Theory
- [3] W. Rudin, Real and Complex Analysis, Third edition, McGraw-Hill, International Editions, 1987.
- [4] I. K. Rana, An Introduction to Measure and Integration, Second Edition, Narosa, 2005.
- [5] D. L. Cohn, Measure Theory, Birkhauser, 1997.
- [6] H. L. Royden, Real Analysis, Third edition, Prentice-Hall of India, 1995.

Third Semester

MA 501 (Functional Analysis)

Credits (L-T-P): 5(4- 1- 0)

Prerequisite: Metric Spaces, Holder's and Minkowski's inequalities, Completeness, Compactness, Heine-Borel and Bolzano-Weierstrass Theorems in \mathbb{R}^n , Continuity, Uniform continuity, Urysohn lemma, Tietze extension theorem.

Normed spaces, Banach spaces, Riesz Lemma, Bounded linear operator, Ascoli theorem, Hahn-Banach extension and separation theorems, Dual of classical spaces l^p , L^p , Banach contraction mapping theorem, Uniform boundedness principle, Open mapping and closed graph theorems, weak convergence, Inner Product space, Hilbert space, Orthonormal sets, Riesz representation theorem, Fourier series - L^2 theory, Bounded linear operators on Hilbert spaces. Spectral theorem for compact self-adjoint operators.

Supplementary Topics: Weak and weak-*topologies, Banach Alaoglu theorem, Spectral theorem for general self-adjoint and normal operators. Riesz representation theorem, dual of $C_0(X)$, X a locally compact space, Gelfand theory. Unbounded operators: definition and examples.

Text Book

G. F. Simmons, Introduction to Topology Modern Analysis

References Books

- [1] B. V. Limaye: Functional Analysis, Revised 2nd edition, New Age International Limited, 1996.
- [2] I. J. Maddox; Elements of Functional Analysis, Cambridge University Press.
- [3] E. Kreyszig; Functional Analysis, John Wiley.

MA 503 (Integral Equations and Calculus of Variation)**Credits (L-T-P): 5(4- 1- 0)****Prerequisite:** Basic differential equation.

Introduction and formulation of integral equation, Classification of Integral Equations., 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 nonlinear Volterra and Fredholm integral equations using Banach Fixed point theorem, Solutions with separable kernels. Characteristic numbers and eigenfunctions, resolvent kernel. Greens function. Calculus of Variations: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extreme.

Text Book

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

References Books

- [1] G. A. Bliss, Calculus of Variations, Open Court Publishing, 1944
- [2] O. Bolza, Lectures on the Calculus of Variations, Dover Publication, New York, 1961.
- [3] J. A. Cochran, The Analysis of Linear Integral Equations, McGraw-Hill, 1972
- [4] Francis B. Hildebrand, Methods of Applied Mathematics, Dover, New York, 2012
- [6] G. F. Roach, Greens Functions, Cambridge University Press, 1995.

Fourth Semester**MA 502 (Mathematical Statistics)****Credits (L-T-P): 5(4- 0- 2)****Prerequisites:** Probability and Calculus

Probability: Quick review, Random Variables, Distribution functions, and Expectation, Probability Inequalities (Markov, Chebyshev, and Jensen), Moments and moment generating functions, Characteristic functions. Special Parametric Families of Univariate Distributions: Discrete Uniform, Binomial, Poisson distributions, Normal distribution, Exponential and Gamma distributions. Joint, marginal and conditional distributions, Covariance and correlation coefficient, stochastic Independence, Joint moment generating Function and moments. Methods of finding Distributions of functions of random variables: The Expectation Technique, The Cumulative distribution function technique, The Transformation technique. Sampling and sampling distributions: Sampling, Distribution of sample, Statistic, Sample moments, Sample Mean, Weak Law of large numbers, Strong Law of large numbers, Central limit theorem. Standard Errors: Standard error of moments, Standard error of Sample Mean. Parametric point estimation: Methods of finding estimators, Method of moments, Maximum likelihood method, Other methods, Properties of point estimators, unbiasedness, sufficiency, efficiency and consistency. Test of Hypotheses: Parametric and non-parametric Hypotheses, Simple and composite Hypotheses, Critical reasons and alternative Hypotheses, Power of a test, Most powerful test, Uniformly most powerful test, Tests on Mean and variance for a sampling from normal distribution (Z-Test, t-Test), Chi-square test of goodness of fit, Chi-square test of independence in contingency tables.

Supplementary Topics: The moment generating function technique for determination of distribution of functions of random variables.

Text Books:

- [1] A. M. Mood, F. A. Graybill and D. C. Boes - Introduction to the Theory of Statistic, Third Edition, TMH, 2001.

References Books

- [1] Alan Stuart and Keith Ord – Kendall’s Advanced Theory of Statistics, Vol-1, Distribution Theory , Sixth Edition, John Wiley & Sons, Reprint 2015.
- [2] Alan Stuart and Keith Ord and Steven Arnold - Kendall’s Advanced Theory of Statistics, Vol – 2A, Classical Inference & Linear Model, Sixth Edition, John Wiley & Sons, Reprint 2015.
- [3] W.W. Hines, D. C. Montgomery, D. M. Goldsman, C. M. Borrer- Probability and Statistics in Engineering, Fourth Edition, Wiley India Pvt. Ltd., Reprint 2009.

MA 504 (Evolutionary Algorithms)**Credits (L-T-P): 5(4- 0- 2)**

Genetic Algorithms: Historical development, GA concepts – encoding, fitness function, population size, selection, crossover and mutation operators, along with the methodologies of applying these operators. Binary GA and their operators, Real Coded GA and their operators. Particle Swarm Optimization: PSO Model, global best, Local best, velocity update equations, position update equations, velocity clamping, inertia weight, constriction coefficients, synchronous and asynchronous updates, Binary PSO. Memetic Algorithms: Concepts of memes, Incorporating local search as memes, single and multi-memes, hybridization with GA and PSO, Generation Gaps, Performance metrics. Differential Evolution: DE as modified GA, generation of population, operators and their implementation. Artificial Bee Colony: Historical development, types of bees and their role in the optimization process.

Supplementary Topic: Multi-Objective Optimization: Linear and nonlinear multi-objective problems, convex and non – convex problems, dominance – concepts and properties, Pareto – optimality, Use of Evolutionary Computations to solve multi objective optimization, bi level optimization, Theoretical Foundations.

References Books

- [1] Coello, C. A., Van Veldhuizen, D.A. and Lamont, G.B.: “Evolutionary Algorithms for solving Multi Objective Problems”, Kluwer.2002
- [2] Deb, K.: “Multi-Objective Optimization using Evolutionary Algorithms”, John Wiley and Sons. 2002
- [3] Deb, K.: “Optimization for Engineering Design Algorithms and Examples”, Prentice Hall of India. 1998
- [4] Gen, M. and Cheng, R.: “Genetic Algorithms and Engineering Design”, Wiley, New York. 1997
- [5] Hart, W.E., Krasnogor, N. and Smith, J.E. : “Recent Advances in Memetic Algorithms”, Springer Berlin Heidelberg, New York. 2005
- [6] Michalewicz, Z.: “Genetic Algorithms+Data Structures=Evolution Programs”, Springer-Verlag, 3rd edition, London, UK.

MA 506 (Numerical Solutions of ODE and PDE)**Credits (L-T-P): 5(4- 0- 2)**

Prerequisites: Basic knowledge of Real analysis and Linear Algebra

Numerical methods for initial value problems: Convergence analysis of the general explicit one-step method, derivation of classical Runge-Kutta methods, Runge-Kutta methods of order greater than four, implicit Runge-Kutta methods. Multistep methods: Predictor-corrector methods: Milne’s methods, Adams-Bashforth Method, absolute stability and accuracy of predictor-corrector methods. Linear multi-step methods: Construction of linear multistep methods, Convergence, Order and error constant, Local and global truncation error, Consistency.

Difference Methods for Boundary value problems.in ODE.

Finite Differences for Linear Equations: Introduction to finite difference formulae, finite difference approximations to derivatives, Linear Parabolic equations-explicit and implicit schemes, Crank Nicholson Method, local truncation error, compatibility, consistency and convergence of the difference methods, Stability analysis (Energy method, Matrix method and Von-Neumann method); Gerschgorin’s theorems, Lax equivalence theorem. Linear Hyperbolic equations, Finite differences, Theoretical concepts of Stability and consistency, order of accuracy, upwind, Lax Friedrichs and Lax-Wendroff schemes. Linear Elliptic Equations-Finite difference schemes, Alternating direction methods.

Supplementary Topic: Introduction to Finite Element Methods, Meshless Methods.

References Books

- [1] G. D. Smith, Numerical solutions to Partial Differential Equations, Brunel University, Clarendon Press, Oxford, 1985.
- [2] J. Strikwerda, Finite Difference Scheme and Partial Differential Equations, SIAM, 1989.
- [3] G. Sewell, Numerical solution of ordinary and partial differential equations, 2ed., Wiley, 2005.
- [4] R. S. Gupta, Elements of Numerical Analysis, Macmillan,
- [5] J.D. Lambert, Computational Methods in Ordinary Differential Equations. Wiley, Chichester, 1991.
- [6] R.J. Leveque, Finite Difference Methods for Ordinary and Partial Differential Equations. SIAM, Philadelphia, 2007.

MA 508 (Information Theory and Coding)

Credits (L-T-P): 5(4- 0- 2)

Prerequisite: Probability theory.

Entropy and Shannon's First Theorem, Mutual information, Data compression, Huffman coding, Asymptotic equipartition property, Universal source coding, Information Channel and Channel Capacity, Differential entropy, Block codes and Convolutional codes, Error correcting codes, Linear Codes, Optimal Codes. block coding, convolutional coding, and Viterbi decoding algorithm

References Books

- [1] G. A. Jones and J. M. Jones, "Information and Coding Theory," Springer, ISBN 1-85233-622-6, 3rd Edition
- [2] T. M. Cover, J. A, Thomas, "Elements of information theory," Wiley Interscience, 2 nd Edition, 2006/
- [3] R. W. Hamming, "Coding and information theory," Prentice Hall Inc., 1980.

MA-520 (Project)

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

A student will choose a topic on advanced mathematics related to but beyond first year courses. Student may choose a research paper. The student will learn the chosen material under the supervision of a teacher. He/She will meet the supervisor regularly (at least once per week) to present the material (s)he has learnt and will update about his/her progress. Two seminars with satisfactory comments on his/her topic are mandatory. Finally, the student is expected to write an expository report of about 15-20 pages on the topic of project and will present this work to a panel of examiners at the end of term.

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

MA 001 (Machine Learning for Data Science)

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

Prerequisites: Basic linear algebra and calculus, introductory-level courses in probability and statistics. Comfort with a programming language (e.g., Matlab, Python) will be essential for completing the homework assignments.

An introduction to supervised and unsupervised techniques for machine learning. Probabilistic and non-probabilistic approaches to machine learning. Classification and regression models, clustering methods, matrix factorization and sequential models. Methods covered in class include linear and logistic regression, support vector machines, boosting, K-means clustering, mixture models, expectation-maximization algorithm, hidden Markov models, among others. Algorithmic techniques for optimization, such as gradient and coordinate descent methods, as the need arises.

References Books:

- [1] T. Hastie, R. Tibshirani and J. Friedman, The Elements of Statistical Learning, Second Edition, Springer.
- [2] C. Bishop, Pattern Recognition and Machine Learning, Springer.
- [3] H. Daume, A Course in Machine Learning, Draft. (<http://ciml.info/>)

MA 002 (Graph Theory)

Credits (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 digraph adjacency matrix of a digraph, counting of labeled and unlabeled trees, polyas theorem.

References Books

- [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 003 (Differential Geometry)

Credits (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 property of geodesic, Jacobi fields, and convex neighborhood. Global result from surfaces, The Gauss Bonnet Theorem, Hopf-Rinnoe theorem, cut points and conjugate points, the Bonnet-Myers theorem.

References Books

- [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 004(Optimization Techniques)**Credits (L-T-P): 3(3-0- 0)****Prerequisite:** Operations Research

Nonlinear programming: Convex sets and Convex functions, definition and basic properties, Differentiable convex and concave functions, Minima and Maxima of Convex and Concave functions, The Fritz John and Karush-Kuhn-Tucker Optimality Conditions, Quadratic programming with linear constraints, Wolfe's Algorithm, Complementary Pivot Algorithm, Separable Programming, Geometric Programming, Search Techniques: Line search for unimodal functions, Fibonacci method of search, Golden Section Search, Steepest descent method, conjugate direction, conjugate direction method, Powell's Quadratic Interpolation Method.

References Books

- [1] J.C. Pant, Introduction to optimization: Operations Research, Jain Brothers, New Delhi, 2002.
- [2] D. G. Luenberger, Yinyu Ye, Linear and nonlinear programming, Springer, 2008.
- [3] M. S. Bazaraa, H. D. Sherali, C. M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley and Sons, 2006.
- [4] A. Ravindran, D. Phillips, and J. Solberg, Operations Research: Principles and Practice, 2nd Ed., Wiley India, 2007.

MA 005 (Elliptic Curves)**Credits (L-T-P): 3(3- 0- 0)**

Rational points on Plane Curves, The group law on a cubic curve, Regular functions; the Riemann-Roch theorem, Basic Theory of Elliptic Curves, The Weierstrass equation for an elliptic curve, The Group Law, Projective Space and the Point at Infinity, Elliptic Curves in Characteristic 2, Singular curves, Reduction of an elliptic curve modulo p , Algorithms for elliptic curves, Torsion points, Elliptic Curves over Finite Fields
The Discrete Logarithm Problem, Elliptic Curve Cryptography.

Reference Books

- [1] J.S. Milne, Elliptic Curves, Book Surge Publishers, 2006
- [2] J. H. Silverman, Arithmetic of Elliptic Curves, Springer, 2006
- [3] Lawrence C. Washington, Elliptic Curves, Taylor & Francis Group, 2008

MA 006 (Discrete Mathematics)**Credits (L-T-P): 3(3- 0- 0)**

Propositional logic, Proof techniques: forward proof, proof by contradiction, contrapositive proofs, proof of necessity and sufficiency. principles of mathematical induction, Strong Induction. Introduction to counting: Basic counting techniques, Pigeonhole principle, Application of pigeon-hole principle, Advanced Counting Technique-inclusion and exclusion, Application of inclusion and exclusion, Introduction to recurrence relation and generating function. Relations and their properties, equivalence relations, closures, Transitive Closure and Warshall's Algorithms, functions, order relation and structure, partially ordered sets, Lattices, Introduction to Graphs: Shortest Path Problem, Dijkstra's Shortest path algorithm, Trees, Minimum Spanning Tree, Application of Trees, Tree Traversal, Finite Boolean Algebra, functions on Boolean Algebra.

References Books

- [1] K. H. Rosen, Discrete Mathematics and its Applications, Tata McGraw-Hill.
- [2] C. L. Liu, Elements of Discrete Mathematics, Tata McGraw-Hill.
- [3] T. Koshy, Discrete Mathematics with Applications, Elsevier.
- [4] R. P. Grimaldi, Discrete and Combinatorial Mathematics, Pearson Education, Asia.
- [5] B. Kolman, R. Busby and S. C. Ross, N. Rehman, Discrete Mathematical Structures, Pearson Prentice Hall.

MA 007 (Fractional Calculus)**Credits (L-T-P): 3(3- 0- 0)**

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 Fractiona 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

References Books

- [1] 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.
- [2] 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.
- [3] I. Podlubny, Matrix approach to discrete fractional calculus. *Fractional Calculus and Applied Analysis*, vol. 3, no. 4, 2000, pp. 359–386.1

MA 008 (Applied Linear Algebra)

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

Review of Linear Algebra; LU-decomposition, QR-decomposition, 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. Applications of Linear Algebra: Linear Programming, Fourier Series, Computer graphics, Difference equations and powers A^k ; Differential equations and e^{At} .

References Books

- [1] S. Axler, *Linear Algebra done right*, Springer
- [2] G. Strang, *Introduction to Linear Algebra*, 4th edition, Cambridge University Press India Pvt Ltd, 2009
- [3] G. Strang, *Linear Algebra and Its Applications*, 4th edition, Brooks/Cole (Cengage Learning), 2006

MA 009 (Commutative Algebra)

Credits (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.

References Books

- [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 010 (Fuzzy theory and applications)

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

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, fuzzy rule-based systems, graphical technique of inference, Development of membership functions: Membership value assignments: intuition, inference, rank ordering, neural networks, genetic algorithms, inductive reasoning. Fuzzy Arithmetic and Extension Principle: Functions of fuzzy sets, extension principle, fuzzy mapping, interval analysis, vertex method and DSW algorithm. Fuzzy Optimization: One dimensional fuzzy optimization, fuzzy concept variables and casual relations, fuzzy cognitive maps, agent-based models.

References Books

- [1] Ross, T. J., "Fuzzy Logic with Engineering Applications", Wiley India Pvt. Ltd., 3rd Ed. 2011
- [2] Zimmerman, H. J., "Fuzzy Set theory and its application", Springer India Pvt. Ltd., 4th Ed. 2006
- [3] Klir, G. and Yuan, B., "Fuzzy Set and Fuzzy Logic: Theory and Applications", Prentice Hall of India Pvt. Ltd. 2002

MA 011 (Design Optimization)**Credits (L-T-P): 3(3-0-0)**

Formulation of a design optimization problems, Local and Global Minima, Pareto optimum, optimality Conditions, Iterative function minimization methods, Iterative methods for constrained problems, Exploratory Methods, Multi-criteria optimization methods, Decision making problem, Introduction to Genetic Algorithm, Parameters of Genetic algorithms, chromosome representation, Encoding, Selection mechanisms, Evolutionary operators, Fitness function, Handling constraints, Penalty function strategy, tournament selection in constrained optimization, Methods of selecting a set of Pareto optimal solutions, Distance method, Pareto set distribution method, Constraint tournament selection method for multi-criteria optimization, Application of Genetic algorithm to solve design optimization problem.

Reference Books

- [1] Andrzej Osyczka, "Evolutionary Algorithms for Single and Multicriteria Design Optimization" Volume 79 of Studies in Fuzziness and Soft Computing, Physica-Verlag Heidelberg, 25-Sep-2001 - Business & Economics - 218 pages.
- [2] Kalyanmoy Deb, "Optimization for Engineering Design: Algorithms and Examples" Prentice Hall India Learning Private Limited; second edition (1995).
- [3] S. S. Rao, "Engineering Optimization: Theory and Practice", New Age International Publishers; Third edition (1 January 2013)

MA 012 (Computational Mathematics with Python)**Credits (L-T-P) : 3 (2- 0- 2)**

Elementary programming 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.

References Books

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

MA-013 (Optimal Control to PDEs)**Credits (L-T-P): 3(2- 0- 2)**

Introduction, optimal control, convex problems, nonconvex problems, Basic concepts for the finite-dimensional case, Linear-quadratic elliptic control problems, Weak solutions to elliptic equations, Linear mappings, Existence of optimal controls, Differentiability in Banach spaces, Adjoint operators, First-order necessary optimality conditions, Construction of test examples, The formal Lagrange method, The adjoint state as a Lagrange multiplier' Higher regularity for elliptic problems, Regularity of optimal controls, Linear-quadratic parabolic control problems, Parabolic optimal control problems, Necessary optimality conditions, Optimal control of semi linear elliptic equations, A semi linear elliptic model problem, Existence of optimal controls, control-to-state operator, Necessary optimality conditions, Pontryagin's maximum principle, Second-order optimality condition.

References Books

- [1] Fredi Tröltzsch, Optimal Control of Partial Differential Equations Theory, Methods and Applications, American Mathematical Society Providence, Rhode Island, 2005.
- [2] J.C.Lions, Optimal Control of Systems Governed by Partial Differential Equations, Springer.

MA-014 (Advanced Optimization Techniques)**Credits (L-T-P): 3(3- 0- 0) :****Prerequisite:** Optimization Techniques

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 Gordon theorem, Lemkis Complementary Pivot algorithm, Linear Fractional Problem, Charnes-Cooper method, method of Gilmore and Gomory, Fletcher Reeves method, Davidon-Fletcher Powell Method, Constrained Optimization, Sequential unconstrained minimization technique, penalty and barrier function methods,

References Books

- [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-015 (Applied Approximation)

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

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.

References Books

- [1] G. Adomian, Nonlinear Linear stochastic operators equations (1986). Academic Press, Inc (London)
- [2] A. M Wazwaz, Partial Differential equation and Solitary waves theory (2009). Higher Education Press and Springer.

MA-016 (Perturbation Methods)

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

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 twoscale approximation, Higher order approximations. Methods of WKB type, Introductory examples, The formal WKB expansion without turning points, Ray methods

References Books

- [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-017 (Dynamic Meteorology)

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

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.

References Books

- [1] S. L. Hess, Introduction to Theoretical Meteorology,, Krieger Pub. Co. Press.
- [2] James, C. Holton, An Introduction to Dynamic Meteorology,, Academic Press, 3rd edition.

MA 018 (Coding Theory)

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

The communication channel, the coding problem, types of codes, block codes, error detecting and error -correcting codes, linear codes, the Hamming metric, description of linear block codes by matrices, dual codes, standard array, syndrome, step-by step, decoding, modular representation , error - correction capabilities of linear codes, Hamming sphere packing bound, Hamming codes, Golay Codes, Perfect Codes, Basics and Algebraic Codes. Linear Block Codes: Generator and parity-check matrices, Minimum Distance, Syndrome decoding, Bounds on minimum distance. Cyclic Codes: Finite fields, Binary BCH codes, RS codes.

Reference Books

- [1] Ramond Hill, A first Course in Coding Theory , Oxford University press, 1990
- [2] W.W. Peterson and E.J. Weldon Jr. Error- Correcting Codes, MIT Press, Cambridge, Massachusetts, 1972

MA 019 (Analytic Number Theory)**Credits (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.

References Books

- [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 020 (Symmetries)**Credits (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.

References Books

- [1] M. Artin, Algebra, Prentice Hall of India (1991).
- [2] D. S. Dummit, R. M. Foote, Abstract Algebra, 2nd edition, John Wiley. 2008

MA 021 (Numerical Analysis with Programming)**Credits (L-T-P): 3(2- 0- 2)**

Errors in computation: Floating point representation, Rounding, Chopping, Arithmetic Operation, Truncation and Taylor Series, Linear Equations and Eigenvalue Problem: Ill-conditioned systems and conditioned number; iterative methods, Eigen value and Eigen vectors; Given's method and Householder method for symmetric matrices; Polynomial methods, Power method; Nonlinear equations: Method of Successive Approximation, Aitken's method, Newton-Raphson, convergence analysis. Interpolation: Lagrange Interpolation, Truncation error in polynomial interpolation, Inverse interpolation, Hermite's interpolation, Piecewise polynomial interpolation: Cubic spline interpolation, Numerical differentiation, Numerical integration: Newton-Cotes Quadrature Formulae, Romberg integration, Gaussian Quadrature (Gauss-Legendre Quadrature Formula).

Laboratory: Implementation of methods discussed in above syllabus.

References Books

- [1] R. S. Gupta, Elements of Numerical Analysis Macmillan, 2009.
- [2] Srimanta Pal, Numerical Methods: Principles, Analysis and Algorithms (Oxford Higher Education)
- [3] Curtis F. Gerald, Patrick O. Wheatley, Applied Numerical Analysis, Pearson, 2003.
- [4] R.L. Burden and J.D. Faires, Numerical Analysis, 7th Edit, Thomson, New York, 2007

MA 022(Dynamic Oceanography)**Credits (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, Sverdrup's solution for the wind driven solution, General Approach to numerical modeling of ocean circulation.

References Books

- [1] G. L. Pickard and W.J. Emery, Descriptive Physical Oceanography, Pergamon Press.
- [2] J. Pedlosky, Geophysical Fluid Dynamics, Springer Verlag.
- [3] Stephen Pond, and G. L. Pickard, Introductory Dynamical Oceanography, Pergamon Press.

MA 023 (Foundations of Cryptography)**Credits (L-T-P): 3(3- 0- 0)**

Introduction, Perfect secrecy, One-time-pad encryption, Indistinguishability-based 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/block ciphers). The Feistel transform and the design of DES. Applications of PRFs/s-PRPs: Chosen-Plaintext Attacks (CPA) security. Modes of operation. 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.

References Books

- [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 024 (Quantum Computing)**Credits (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.

References Books

- [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.

MA 025 (Computational Number Theory)**Credits (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

References Books

- [1] V. Shoup, A Computational Introduction to Number Theory and Algebra, Cambridge University Press.
- [2] J. H. Silverman and John Tate, Rational Points on Elliptic Curves, Springer International Edition.
- [3] D. R. Hankerson, A. J. Menezes and S. A. Vanstone, Guide to Elliptic Curve Cryptography, Springer-Verlag.
- [4] H. Cohen, A Course in Computational Algebraic Number Theory, Springer-Verlag.

MA 026(Queuing Theory & Stochastic Process)**Credits (L-T-P): 3(3-0-0)**

Queuing Theory, Kendall notation, steady and transient state, Single server with finite and infinite capacity, multiple server with finite and infinite capacity, Random Process, Mean variance and correlation, Stationary random process, auto correlation, cross correlation, Binomial, Normal and Poisson process, birth and death process.

References Books

- [1] Sunderapandian, V., Probability, Statistics and Queuing theory, PHI.
- [2] Alexander M. Mood, Franklin A Graybill, Duane C. Boes, Introduction to the theory of Statistics, TMH.
- [3] R. Nelson, Probability, Stochastic Process and Queuing theory, Springer, New York

MA 027 (Sampling Theory & Statistical Inference)**Credits (L-T-P): 3(3-0-0)**

Sampling theory, distribution of sample, statistic and sample moments, sample mean, law of large number, central limit theorem, sampling from normal distribution, parametric point estimation, method of moments, method of maximum likelihood, parametric interval estimation, parametric and nonparametric test.

References Books

- [1] Gupta and Kapoor, Fundamental of mathematical statistics, S. Chand.
- [2] Alexander M. Mood, Franklin A Graybill, Duane C. Boes, Introduction to the theory of Statistics, TMH.
- [3] R. Nelson, Probability, Stochastic Process and Queuing theory, Springer, New York

MA 028 (Mathematical modeling with MATLAB)**Credits (L-T-P): 3(2-0-2)**

MATLAB Environment, M-Files, Scripts, MATLAB Functions, Program design and development, Mathematical Modeling, Proportionality and geometric similarity, Modeling with proportionality, Empirical modeling, Discrete system modeling, Time series model, Continuous system modeling, Differential equation solution, Regression models, Interpolation and series, Symbolic processing with MATAB: Symbolic expressions and algebra, Algebraic and transcendental equations, Linear programming: formulation and Solution.

References Books

- [1] R. Illner et al. "Mathematical Modelling: A Case Studies Approach", AMS, 2005.
- [2] E. Bender. "Introduction to Mathematical Modelling", Dover, 2000.
- [3] Amos Gilat, "MATLAB, An Introduction with Applications", 2009.
- [4] M.C. Ferris, O.L. Managasarian, Stephen J. Wright, "Linear Programming with MATLAB", SIAM, 2007.

MA 029 (Methods of Applied Mathematics)**Credits (L-T-P): 3(3-0-0)**

Pade's Approximation, 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 Decomposition method, and Modified Adomian decomposition method and their Comparison between alternative (Direct Computation method, successive approximation method). Integral-Differential Equations. Singular Integral Equations, Generalized Abel Integral Equation, Weakly-singular Volterra Equations.

Reference Books

- [1] G. F. Roach, Greens Functions, Cambridge University Press, 1995.
- [2] G. Adomian, Nonlinear Stochastic Operator Equations, Academic Press, INC
- [3] G. A. Bliss, Calculus of Variations, Open Court Publishing, 1944
- [4] O. Bolza, Lectures on the Calculus of Variations, Dover Publication, New York, 1961.
- [5] J. A. Cochran, The Analysis of Linear Integral Equations, McGraw-Hill, 1972

MA 030 (Finite Element Methods for Partial Differential Equations)**Credits (L-T-P): 3(3-0-0)**

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 Cea 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 CAS.

Reference Books

- [1] P. G. Ciarlet, The Finite Element Method for Elliptic Problems, North-Holland, 1978.
- [2] J. N. Reddy, An Introduction to Finite Element Method, Mc-Graw Hill, 1993.
- [3] S. C. Brenner, L. R. Scott, The 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, Cengage Learning, 2007.

MA 031 (Fluid Mechanics)

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

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.

Reference Books

- [1] A. J. Chorin, J. E. Marsden, A Mathematical Introduction to Fluid mechanics, Springer-Verlag, 1999.
- [2] P. K. Kundu, I. M. Cohen, Fluid Mechanics (3rd edition) Elsevier Science and Technology, 2002.
- [3] H. Schlichting, K. Gersten, Boundary Layer Theory Springer-Verlag, 1985.
- [4] F. Chorlton, Textbook of Fluid Dynamics 1st Edition, CBS Publisher, 2004
- [5] G. K. Batchelor, Introduction to Fluid dynamics, Cambridge University Press.

MA 032 (Computational Fluid Dynamics)

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

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 discretization, 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.

Reference Books

- [1] C. A. J. Fletcher, Computational Techniques for Fluid Dynamics, Volume 1 & 2, Springer Verlag, 1992.
- [2] C. Y. Chow, Introduction to Computational Fluid Dynamics, John Wiley, 1979.
- [3] M. Holt, Numerical Methods in Fluid Mechanics, Springer Verlag, 1977.
- [4] H. J. Wirz, J. J. Smolderen, Numerical Methods in Fluid Dynamics, Hemisphere, 1978.
- [5] J. D. Anderson, Computational Fluid Dynamics, The Basics with Applications, McGraw-Hill, 1995

Minor correction in MA305 (B.Sc. Program)

The course **MA305 Probability and Statistics** is 6 credit courses. It is now replaced by following two components.

1. **MA305: Probability and Statistics** - 4 credit course (4-0-0)
2. **MA305L: Probability and Statistics Lab** - 2 credit course (0-0-2)

These corrections are effective from the session 2018-19.

Course Name: **Probability & Statistics**

Course Code: **MA305**

Credits: **04 (4-0-0)**

Notion of Probability: Random experiments, Sample space, Probability axioms, equally likely outcome problems, Conditional probability, Bay's theorem.

Random variables: Concepts, discrete and continuous random variables, Cumulative distribution function, Probability mass/density functions, Mathematical expectation. Moments, Moment generating function, Characteristic function. Discrete distributions: uniform, binomial, Poisson, Geometric, Negative Binomial distributions. Continuous distributions: Uniform, Normal, Exponential, Gamma distributions

Joint cumulative distribution Function and its properties, Joint probability density functions – marginal and conditional distributions. Expectation of a function of two random variables, Conditional expectations, Independent random variables, Covariance and correlation coefficient.

Linear regression for two variables, The rank correlation coefficient. Chebyshev's inequality, statement and interpretation of (weak) law of large numbers and strong law of large numbers. Central Limit Theorem for independent and identically distributed random variables with finite variance.

Some Applications: list-model, a random graph, Polya's Urn Model

REFERENCES:

1. Robert V. Hogg, Joseph W. Mc Kean and Allen T. Craig. Introduction of Mathematical Statistics, Pearson Education, Asia, 2007
2. Irvin Miller and Marylees Miller, John E. Freund's Mathematical Statistics with Applications (7thEdn), Pearson Education, Asia, 2006.
3. Sheldon Ross, Introduction to Probability Models (9th Edition), Academic Press, Indian Reprint, 2007

Course Name: **Probability and Statistics**

Course Code: **MA305L**

Credits: **02 (0-0-2)**

Computational exercises based on theory component using MATLAB/Python/R or any other CAS.