UNIVERSITY OF DELHI

M.A./M.SC. MATHEMATICS

TWO-YEAR FULL TIME PROGRAMME

RULES, REGULATIONS AND COURSE CONTENTS

DEPARTMENT OF MATHEMATICS
UNIVERSITY OF DELHI
DELHI-110007

July 2014

University of Delhi
Examination Branch

Check List of Course Evaluation for AC Consideration

S. No.	Parameter	Status
1	Affiliation	$\surd$
2	Programme Structure	$\surd$
3	Codification of Papers	$\surd$
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5	Reappearance in Passed papers	$\surd$
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MASTER OF ARTS/SCIENCE
(MATHEMATICS)
TWO-YEAR FULL-TIME PROGRAMME

AFFILIATION

The proposed programme shall be governed by the Department of Mathematics, Faculty of Mathematical Sciences, University of Delhi, Delhi-110007.

PROGRAMME STRUCTURE

The master's programme in Mathematics is divided into two parts as hereunder. Each part will consist of two semesters.

Part I	First Year	Semester 1	Semester 2
Part II	Second Year	Semester 3	Semester 4

The courses prescribed for various semesters shall be the following:

Semester I	
MATH14-101	FIELD THEORY
MATH14-102	COMPLEX ANALYSIS
MATH14-103	MEASURE AND INTEGRATION
MATH14-104	DIFFERENTIAL EQUATIONS
Semester II	
MATH14-201	MODULE THEORY
MATH14-202	TOPOLOGY-I
MATH14-203	FUNCTIONAL ANALYSIS
MATH14-204	FLUID DYNAMICS
Semester III	
	Anyone of the following
MATH14-301(A)	ALGEBRAIC TOPOLOGY
MATH14-301(B)	REPRESENTATION OF FINITE GROUPS
MATH14-301(C)	COMMUTATIVE ALGEBRA
	Anyone of the following
MATH14-302(A)	FOURIER ANALYSIS
MATH14-302(B)	MATRIX ANALYSIS
MATH14-302(C)	THEORY OF BOUNDED OPERATORS
	Anyone of the following
MATH14-303(A)	ADVANCED COMPLEX ANALYSIS
MATH14-303(B)	MEASURE THEORY
MATH14-303(C)	TOPOLOGY-II

	Anyone of the following
MATH14-304(A)	CODING THEORY
MATH14-304(B)	COMPUTATIONAL FLUID DYNAMICS
MATH14-304(C)	COMPUTATIONAL METHODS FOR ODES
MATH14-304(D)	MATHEMATICAL PROGRAMMING
MATH14-304(E)	METHODS OF APPLIED MATHEMATICS
MATH14-304(F)	GRAPH THEORY
Semester IV	
	Anyone of the following
MATH14-401(A)	ALGEBRAIC NUMBER THEORY
MATH14-401(B)	THEORY OF NON-COMMUTATIVE RINGS
MATH14-401(C)	SIMPLICIAL HOMOLOGY THEORY
MATH14-401(D)	ADVANCED GROUP THEORY
	Anyone of the following
MATH14-402(A)	ABSTRACT HARMONIC ANALYSIS
MATH14-402(B)	FRAMES AND WAVELETS
MATH14-402(C)	OPERATORS ON HARDY-HILBERT SPACES
MATH14-402(D)	THEORY OF UNBOUNDED OPERATORS
	Anyone of the following
MATH14-403(A)	CALCULUS ON $\mathbb{R}^n$
MATH14-403(B)	DIFFERENTIAL GEOMETRY
MATH14-403(C)	TOPOLOGICAL DYNAMICS
	Anyone of the following
MATH14-404(A)	ADVANCED CODING THEORY
MATH14-404(B)	ADVANCED FLUID DYNAMICS
MATH14-404(C)	COMPUTATIONAL METHODS FOR PDES
MATH14-404(D)	CRYPTOGRAPHY
MATH14-404(E)	DYNAMICAL SYSTEMS
MATH14-404(F)	OPTIMIZATION TECHNIQUE AND CONTROL THEORY

SCHEME OF EXAMINATIONS

1. English shall be the medium of instruction and examination.

2. Examinations shall be conducted at the end of each Semester as per the Academic Calendar notified by the University of Delhi.

3. Each course will carry 100 marks and have two components: Internal Assessment 30% marks and End-Semester Examination 70% marks.

4. The system of evaluation shall be as follows:

4.1 Internal assessment will be based on classroom participation, seminar, term courses, tests, quizzes. The weightage given to each of these components shall be decided and announced at the beginning of the semester by the individual teacher responsible for the course. No special classes will be conducted for a student during other semesters, who fails to participate in classes, seminars, term courses, tests, quizzes and laboratory work.

4.2 The remaining 70 marks in each paper shall be awarded on the basis of a written examination at the end of each semester. The duration of written examination for each paper shall be three hours.

5. Examinations for courses shall be conducted only in the respective odd and even Semesters as per the Scheme of Examinations. Regular as well as Ex-Students shall be permitted to appear/re-appear/improve in courses of Odd Semesters only at the end of Odd Semester and courses of Even Semesters only at the end of Even Semesters.

PASS PERCENTAGE & PROMOTION CRITERIA:

(a) The minimum marks required to pass any paper in a semester shall be 40% in theory and 40% in Practical, wherever applicable. The student must secure 40% in the End Semester Examination and 40% in the total of End Semester Examination & Internal Assessment of the paper for both theory & practical separately.

(b) No student will be detained in I or III Semester on the basis of his/her performance in I or III Semester examination; i.e. the student will be promoted automatically from I to II and III to IV Semester.

(c) A student shall be eligible for promotion from Ist year to 2nd year of the course provided he/she has passed 50% papers of I and II Semester taken together. However, he/she will have to clear the remaining paper/s while studying in the 2nd year of the programme.

(d) Students who do not fulfill the promotion criteria (c) above shall be declared fail in the Part concerned. However, they shall have the option to retain the marks in the papers in which they have secured Pass marks as per Clause (a) above.

(e) A student who has to reappear in a paper prescribed for Semester I/III may do so only in the odd Semester examinations to be held in November/December. A student who has to reappear in a paper prescribed for Semester II/IV may do so only in the even Semester examinations to be held in April/May.

REAPPEARANCE IN PASSED PAPERS

(a) A student may reappear in any theory paper prescribed for a semester, on foregoing in writing her/his previous performance in the paper/s concerned. This can be done once only in the immediate subsequent semester examination only (for example, a student

reappearing in a paper prescribed for Semester I examination, may do so along with the immediate next Semester III examinations only)

(b) A candidate who has cleared the papers of Part II (III & IV Semesters) may reappear in any paper of III or IV Semester only once, at the immediate subsequent examination on foregoing in writing her/his previous performance in the paper/s concerned, within the prescribed span period.

(Note: The candidate of this category will not be eligible to join any higher course of study)

(c) In the case of reappearance in a paper the result will be prepared on the basis of candidates current performance in the examination.

(d) In the case of a candidate, who opts to re-appear in any paper/s under the aforesaid provisions, on surrendering her/his earlier performance but fails to re-appear in the paper/s concerned, the marks previously secured by the candidate in the paper/s in which he/she failed to re-appear shall be taken into account while determining her/his result of the examination held currently.

(e) Reappearance in Practical examinations, dissertation, project and filed work shall not be allowed.

(f) A student who reappears in a paper shall carry forward the internal assessment marks, originally awarded.

NOTES: (1) Each course will have 5 credits: 4 lectures, 1 discussion and 1 tutorial per week.

(2) In the beginning of the respective semesters, the Department will announce the list of elective courses which will be offered during the semester depending upon the availability of lecturers and the demand of electives.

DIVISION CRITERIA

A student who passes all the papers prescribed for Part I & II examinations would be eligible for the degree. Such a student shall be categorized on the basis of the combined result of Part I and II examinations as follows:-

(1) 60% or more : Ist Division
(2) 50% or more but less than 60% : IInd Division
(3) 40% or more but less than 50% : IIIrd Division

SPAN PERIOD No student shall be admitted as a candidate for the examination for

any of the Parts/Semesters after the lapse of four years from the date of admission to the Semester 1 of the masters programme in Mathematics.

Semester I

MATH14-101: Field Theory

Fields and their extensions, splitting fields, the algebraic closure of a field, separability, automorphisms of field extensions, the fundamental theorem of Galois theory, roots of unity, finite fields, primitive elements, Galois theory of equations, the solution of equations by radicals.

Reference books.

[1] P.M. Cohn, Basic Algebra, Springer International Edition, 2003.
[2] P.M. Cohn, Classic Algebra, John Wiley & Sons Ltd., 2000.
[3] N. Jacobson, Basic Algebra I & II, Hindustan Publishing Co., 1989.
[4] T. W. Hungerford, Algebra, Springer-Verlag, 1981.

MATH14-102: Complex Analysis

Analytic functions as mappings, conformal mappings, Mobius transformations, branch of logarithm, Riemann Stieltjes integrals.

Power series representation of analytic functions, maximum modulus theorem, index of a closed curve,Cauchy's theorem and integral formula on open subsets of $\mathbb{C}$.

Homotopy, homotopic version of Cauchy's theorem, simple connectedness, counting of zeros, open mapping theorem, Goursat's theorem, Classification of singularities, Laurent series.

Residue, Contour integration, argument principle, Rouche's theorem, Maximum principle, Schwarz' lemma.

Text book(s).

[1] J. B. Conway, *Functions of One Complex Variable*, Narosa, New Delhi, 2002.

Reference books.

[1] L.V. Ahlfors, *Complex Analysis*, Mc. Graw Hill Co., New York, 1988.
[2] T. W. Gamelin, *Complex Analysis*, Springer Verlag, 2008.
[3] L. Hahn, B. Epstein, *Classical Complex Analysis*, Jones and Bartlett, India, New Delhi, 2011.
[4] D. Ullrich, *Complex Made Simple*, Amer. Math. Soc., 2008.

MATH14-103: Measure and Integration

Lebesgue outer measure, measurable sets, regularity, measurable functions, Borel and Lebesgue measurability, non-measurable sets

Integration of nonnegative functions, the general integral, integration of series, Riemann and Lebesgue integrals

Functions of bounded variation, Lebesgue differentiation theorem, differentiation and integration, absolute continuity of functions, Measures and outer measures, measure spaces, integration with respect to a measure

The L^p spaces, Holder and Minkowski inequalities, completeness of L^p spaces, convergence in measure, almost uniform convergence, Egorov's theorem.

Text book(s).

[1] G. de Barra, Measure and Integration. New Age International (P) Ltd., New Delhi, 2006.

Reference books.

[1] M. Capinski and E. Kopp, Measure, Integral and Probability, Springer-Verlag, 2003
[2] E. Hewitt and K. Stromberg, Real and Abstract Analysis, Springer, Berlin, 1988
[3] H. L. Royden, Real Analysis, 3rd Edition, Prentice Hall, 1988

MATH14-104 Differential Equations

Well posed problems. Existence, uniqueness and continuity of the solution of ordinary differential equation of first order, Picard's method. Existence and uniqueness of the solution of simultaneous differential equations of first order and ordinary differential equation of higher order. Sturm separation and comparison theorems, Homogeneous linear systems, Non-homogeneous Linear systems, Linear systems with constant coefficients.

Two point boundary value problems, Greens function, Construction of Green functions, Sturm-Lioville systems, Eigen values and Eigen functions. Stability of autonomous system of differential equations, critical point of an autonomous system and their classification as stable, asymptotically

stable, strictly stable and unstable. Stability of linear systems with constant coefficients. Linear plane autonomous systems, Perturbed systems. Method of Lyapunov for nonlinear systems.

Fourier transform and its application to solution of PDEs, Boundary value problems, Maximum and minimum principles, Uniqueness and continuous dependence on boundary data, Solution of the Dirichlet and Neumann problem for a half plane by Fourier transform method. Solution of Dirichlet problem for a circle in form of Poission integral formula. Theory of Green function for Laplace equation in two dimension and its application in solution of Dirichlet and Neumann problem for half plane and circle, Theory of Green function for Laplace equation in three dimension and its application in solution of Dirichlet and Neumann Problem for semi-infinite space and sphere.

Wave equation, Helmholtz's first and second theorems, Green's function for wave equation. Duhamel's principles for wave equation, Diffusion equation, Solution of initial boundary value problems for the diffusion equation, Green's function for diffusion equation, Duhamel's principles for heat equation.

Text book(s).

[1] E.A. Coddington, An Introduction to Ordinary Differential Equations, Dover, 1989
[2] Tyn Myint-U, Ordinary Differential Equations, Elsevier North-Holland, 1978
[3] Ian N. Sneddon, Elements of Partial Differential Equations, McGraw-Hill, 1986

Reference books.

[1] G.F. Simmons, Ordinary Differential Equations with applications and Historical notes, McGraw-Hill, 1991.
[2] Tyn Myint-U Linear Partial Differential Equations for Scientists and Engineers, Birkhauser, 2007.
[3] S.L.Ross, Differential Equation, Wiley India, 2004

Semester II

MATH14-201: Module Theory

Modules, Basic Concepts, Direct product and Direct sums, Exact sequences, Split exact sequences, Nakayama lemma, Free modules, Modules over P.I.D., Chain conditions, Hilbert basis theorem, Categories and Functors, Hom functors, Tensor product of modules, Semi simple modules, Projective and Injective modules, Baer's criterion, Divisible modules.

Reference books.

[1] P.M. Cohn, Classic Algebra, John Wiley & Sons Ltd., 2000.
[2] P.M. Cohn, Basic Algebra, Springer International Edition, 2003.
[3] D. S. Dummit & R.M. Foote, Abstract Algebra, Wiley India Pvt. Ltd.
[4] T.W. Hungerford, Algebra, Springer-Verlag, 1981.
[5] N. Jacobson, Basic Algebra, Volume II, Hindustan Publishing Co., 1989.

MATH14-202: Topology - I

Topological spaces, derived concepts: interior, closure, boundary and limit points of subsets, basis and subbasis for a topology, order topology, subspaces, continuous functions, homeomorphism, product topology, metrisability of products of metric spaces, connected spaces, components, path connected spaces, local connectedness, local path-connectedness, convergence: sequences and nets, Hausdorff spaces, 1st and 2nd countable spaces, separable and Lindelöf spaces, compactness, Tychonoff Theorem, Bolzano-Weierstrass property, countable compactness.

Reference books.

[1] G. E. Bredon, Topology and Geometry, Springer-Verlag, 2005.
[2] J. Dugundji, Topology, Allyn and Bacon, 1970.
[3] J.L. Kelley, General Topology, Springer-Verlag, 2005.
[4] J. R. Munkres, Topology, second edition, Pearson Education, 2003.
[5] T. B. Singh, Elements of Topology, CRC Press, 2013.
[6] S. Willard, General Topology, Dover Publications, Inc. N.Y., 2004.

MATH14-203: Functional Analysis

Normed spaces, Banach spaces, finite dimensional normed spaces and subspaces, compactness and finite dimension. Bounded and continuous linear

operators, linear operators and functionals on finite dimensional spaces. Normed spaces of operators, dual space.

Hilbert spaces, orthogonal complements and direct sums, Bessel inequality, total orthonormal sets and sequences. Representation of functionals on Hilbert spaces. Hilbert adjoint operator. Self-adjoint, unitary and normal operator.

Hahn Banach theorems for real / complex and normed spaces. Adjoint operator, reflexive spaces. Uniform boundedness theorem strong and weak convergence, convergence of sequences of operators and functionals. Open mapping theorem, closed graph theorem

Spectrum of an operator, spectral properties of bounded linear operators, non-emptiness of the spectrum.

Text book(s).

[1] E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley and Sons (Asia) (2011).

Reference books.

[1] G. Bachman and L. Narici, Functional Analysis, Dover Publication, N.Y. (2000).
[2] R. Bhatia, Notes on Functional Analysis, Hindustan Book Agency (India)(2009).
[3] M. Schechter, Principles of Functional Analysis, AMS, 2002.

Math14-204 Fluid Dynamics

Classification of fluids, the continuum model, Eulerian and Lagrangian approach of description. Differentiation following fluid motion. Irrotational flow,vorticity vector, equi-potential surfaces. Streamlines, pathlines, streak lines of the particles, stream tube and stream surface. Mass flux density, conservation of mass leading to equation of continuity. (Euler's form.) Conservation of momentum and its mathematical formulation: Euler's form. Integration of Euler's equation under different conditions. Bernoulli's equation, steady motion under conservative body forces,

Boundary surface, Theory of irrotational motion, Kelvin's minimum energy and circulation theorems, potential theorems. Some two-dimensional flows

of irrotational, incompressible fluids. Complex potential. Sources, sinks, doublets and vortices. Milne-Thomson circle theorem, Images with respect to a plane and circles. Blasius theorem.

Three-dimensional flows. Sources, sinks, doublets. Axi-symmetric flow and Stokes stream function. Butler sphere theorem, Kelvin's inversion theorem and Weiss's sphere theorem. Images with respect to a plane and sphere. Axi-symmetric flows and stream function. Motion of cylinders and spheres.

Viscous flow, stress and strain analysis. Stokes hypothesis, The Navier-Stokes equations of motion. Some exactly solvable problems in viscous flows, steady flow between parallel plates, Poiseuille flow, steady flow between concentric rotating cylinders.

Text book(s).

[1] F.Chorlton : Text book of Fluid Dynamics , CBS 2004.

Reference books.

[1] P.K. Kundu and I.M. Cohen, Fluid Mechanics, Academic Press, 2005.
[2] L.M.MilneThomson, Theoretical Hydrodynamics, The Macmillan company, USA, 1969.
[3] N.E.Neill and F. Chorlton, Ideal and incompressible fluid dynamics, Ellis Horwood Ltd, 1986.
[4] N.E.Neill and F. Chorlton, Viscous and compressible fluid dynamics, Ellis Horwood Ltd, 1986.
[5] D.E.Rutherford: Fluid Dynamics, Oliver and Boyd Ltd, London, 1978.

Semester III

MATH14-301(A): Algebraic Topology

Homotopic maps, homotopy type, retract and deformation retract. Fundamental group. Calculation of fundamental groups of n-sphere, the cylinder, the torus, and the punctured plane. Brouwer fixed-point theorem, the fundamental theorem of algebra, free products, free groups, Seifert-Van Kampen theorem and its applications. Covering projections, the lifting theorems, relations with the fundamental group, universal covering space. The Borsuk-Ulam theorem, classification of covering spaces.

Reference books.

[1] G.E. Bredon, Geometry and Topology, Springer-Verlag, 2005.
[2] W.S. Massey, A Basic Course in Algebraic Topology, Springer, 1991.
[3] J.J. Rotman, An Introduction to Algebraic Topology, Springer-Verlag, 2004.
[4] T. B. Singh, Elements of Topology, CRC Press, 2013.
[5] E.H. Spanier, Algebraic Topology, Springer-Verlag, 1989.

MATH14-301(B): Representation of Finite Groups

Representation of groups, right regular representation, coset representation, matrix representation, linear representation, trivial representation, equivalent matrix representations, G-modules, automorphism representations, characters, class function, reducibility, reducible and irreducible G-modules, contra gradient representation, permutation representations, complete irreducibility, Maschke's theorem for matrix representations and G-modules, Schur's lemma for matrix representations and G-modules, commutant (endomorphism) algebra.

Elementary property of group characters, orthogonality relations, inner product for functions on a group G, orthogonal functions, character relations of the first kind, simple and compound characters, group algebra, character table, character relatioins of the second kind, character table for finite abelian groups, the lifting process, linear characters.

Induced representations, induced characters, restricted character, reciprocity theorem of Frobenius, character tables for alternating groups of degree 4 and 5, conjugate characters, Clifford's theorem, tensor products and Mackey's theorem, Algebraic numbers and conjugates, algebraic integers and their properties, representation of group algebras, Burnside's (p,q)-theorem, Frobenius groups.

Text book(s).

[1] James Gordan and Martin Lieback, Representations and characters of groups, Cambridge University Press, Cambridge, 2001.

Reference books.

[1] Charles W. Curtis and Irving Reiner, Representation Theory of finite groups and associative algebras, AMS Chelsea Publishing, American Mathematical Society reprint, 2006.

[2] William Fulton and Joe Harris, Representation Theory: A first course, Springer-Verlag, New York Inc., 1991.
[3] I. Martin Isaacs, Character Theory of finite groups, AMS Chelsea Publishing, American Mathematical Society reprint, 2006.
[4] Walter Ledermann, Introduction to group characters, Cambridge University Press, Cambridge, 1987.
[5] J. P. Serre, Linear representation of finite groups, Springer-Verlag, 1977.

MATH14-301(c): Commutative Algebra

Extension and Contraction of ideals, Prime spectrum of Rings, Jacobson radical of a ring, Prime avoidance lemma, Rings of formal power series, Restriction and extension of scalars.

Localisation, Local properties, Extended & contracted ideals in rings of fractions, Primary decomposition, First and second uniqueness theorem of primary decomposition, Noetherian rings, Primary decomposition in Noetherian rings, Artin rings, Structure theorem for Artin rings.

Integral dependence, Going up theorem, Going down theorem, Integrally closed domains, Valuation rings, Hilbert's Nullstellensatz theorem, Discrete valuation rings, Dedekind domains, Fractional ideals.

Text book(s).

[1] M.F. Athiyah & I.G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 1969.

Reference books.

[1] Balwant Singh, Basic Commutative Algebra, World Scientific Publishing Co., 2011.
[2] D. Eisenbud, Commutative Algebra with a view towards algebraic geometry, Springer Verlag, 1995.
[3] O. Zariski & P. Samuel, Commutative Algebra, Vol. 1 & 2, Springer-Verlag, 1975.
[4] R.Y. Sharp, Steps in Commutative Algebra, Cambridge University Press, 1990

MATH14-302(a): Fourier Analysis

Convergence and divergence of Fourier series, Fejer's theorem, approximate indentities, the classical kernels [Fejer's, Poisson's and Dirichlet's summability in norm and pointwise summability], Fatou's theorem.

The inequalities of Hausdorff and Young, examples of conjugate function series, the Fourier tranform, kernels on $\mathbb{R}$.

Basic properties of topological groups, separation properties, subgroups, quotient groups and connected groups, Notion of Haar measure on topological groups with emphasis on $\mathbb{R}, \mathbb{T}$ and $\mathbb{Z}$ and some simple matrix groups, $L^1(G)$ and convolution with special emphasis on $L^1(\mathbb{R})$, $L^1(\mathbb{T})$ and $L^1(\mathbb{Z})$.

Plancherel theorem on abelian groups, Plancherel measure on $\mathbb{R}, \mathbb{T}$ and $\mathbb{Z}$, maximal ideal space of $L^1(G)$ (G an abelian topological group).

Text book(s).

[1] Y. Katznelson, Introduction to Harmonic Analysis, John Wiley, 2004.

Reference books.

[1] H. Helson, Harmonic Analysis, Addison-Wesley, 983, Hindustan Pub. Co., 1994.
[2] E. Hewitt and K.A. Ross, Abstract Harmonic Analysis, Vol I, Springer-Verlag, 1993

MATH14-302(B): Matrix Analysis

Closed subgroups of general linear group. Examples and their compactness and connectedness. Matrix exponential.

Norm for vectors and matrices. Analytic properties of vector norms. Geometric properties of vector norms. Matrix norms. Error in inverses and solution of linear systems.

Location and perturbation of eigenvalues. Geršgorin discs, other inclusion regions. Positive definite matrices.

Polar form and singular value decomposition. The Schur product theorem. Positive semi-definite ordering. Inequalities for positive definite matrices. Majorisation and doubly stochastic matrices.

Text book(s).

[1] R. A. Horn and C. R. Johnson, Matrix Analysis, Cambridge University Press (2010)
[2] B. C. Hall, Lie Groups, Lie Algebras, and Representations: An Elementary Introduction, Springer-Verlag (2003)

Reference books.

[1] R. Bhatia, Matrix Analysis Springer-Verlag (1996)
[2] C. D. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM (2000).
[3] F. Zhang, Matrix Theory (Basic Results and Techniques), Springer-Verlag (1999).

MATH14-302(c): Theory of Bounded Operators

Spectrum of a bounded operator: Review of basic concepts, point, continuous and residue spectrum, and of notions of uniform, strong and weak operator convergence on the space of bounded linear operators. Approximate point spectrum and compression spectrum, spectral mapping theorem for polynomials.

Compact linear operators: Basic properties, adjoint of compact operators, Spectral properties of compact operators, the Fredholm alternative.

Spectral theory of self-adjoint operators : spectral properties of self adjoint operators, positive operators and their properties, spectral representation of a self adjoint compact operator, spectral family of a self adjoint operator and its properties, spectral representation of a self adjoint operator, continuous functions of self-adjoint operators.

Polar decomposition, singular values, trace class operators, trace norm and trace, Hilbert Schmidt operators.

Reference books.

[1] R. Bhatia, Notes on Functional Analysis, TRIM series, Hindustan Book Agency, India, 2009.
[2] J.E. Conway, A course in Operator Theory, Graduate Studies in Mathematics, Volume 21, AMS (1999)
[3] E. Kreyszig, Introductory Functional Analysis with Applications,John Wiley and Sons (2001)
[4] Martin Schechter, Principles of Functional Analysis, American Mathematical Society, (2004)

MATH14-303(A): Advanced Complex Analysis

Hadamard's three circles theorem, Phragmen-Lindelof theorem. The space of continuous functions $C(G, \Omega)$, spaces of analytic functions, Hurwitz's thorem, Montel's theorem, spaces of meromorphic functions.

Riemann mapping theorem, Weiersirass' factorization theorem, factorization of the sine function. Runge's theorem, simply connected regions, Mittag-Leffler's theorem

Harmonic functions, maximum and minimum principles, harmonic functions on a disk, Harnack's theorem, sub-harmonic and super-harmonic functions, maximum and minimum principles, Dirichlet problem, Green's function.

Entire functions. Jensen's formula, Bloch's theorem, Picard theorems, Schottky's theorem.

Text book(s).

[1] J. B. Conway, *Functions of One Complex Variables*, 2nd ed, Narosa Publishing House, New Delhi, 2002.

Reference books.

[1] L.V. Ahlfors, *Complex Analysis*, Mc. Graw Hill Co., New York, 1988.
[2] L. Hahn, B. Epstein, *Classical Complex Analysis*, Jones and Bartlett, India, New Delhi, 2011.
[3] W. Rudin, *Real and Complex Analysis*, McGraw-Hill, 1987
[4] D. Ullrich, *Complex Made Simple*, Amer. Math. Soc., 2008

MATH14-303(B): Measure Theory

Signed measures, complex measures, Hahn decomposition theorem, Jordan decomposition theorem, mutually singular measures, Radon-Nikodym theorem, Lebesgue decomposition.

Caratheodory extension theorem, Lebesgue measure on $\mathbb{R}^n$, uniqueness up to multiplication by a scalar of Lebesgue measure in $\mathbb{R}^n$ as a translation invariant Borel meaasure.

Riesz representation theorem for bounded linear functionals on L^p-spaces, Product measures, Fubini's theorem, Tonelli's theorem.

Baire sets, Baire measures, continuous functions with compact support, regularity of measures on locally compact spaces, Regularity of Lebesgue measure in $\mathbb{R}^n$. Riesz Markov representation theorem.

Text book(s).

[1] H. L. Royden, Real Analysis, 3rd Edition, Prentice Hall, 1988

Reference books.

[1] C. D. Aliprantis and O. Burkinshaw, Principles of Real Analysis, Academic Press, Indian Reprint, 2011
[2] A. K. Berberian, Measure and Integration, AMS Reprint, 2011
[3] P. R. Halmos, Measure Theory, East-West Press Pvt. Ltd., 1978
[4] M. E. Taylor, Measure Theory, AMS, 2006

MATH14-303(C): Topology - II

Quotient spaces, identification maps, cones, suspensions, local compactness and one-point compactification. proper maps, regularity, complete regularity, the Stone-Cech compactification, normality, Urysohn lemma, Tietze extension theorem, Urysohn metrization theorem, Nagata-Smirnov metrisation theorem, paracompactness, characterizations of paracompactness in regular spaces, partition of unity.

Reference books.

[1] J. Dugundji, Topology, Allyn and Bacon, 1970.
[2] R. Engelking, General Topology, Heldermann, 1989.
[3] J.L. Kelley, General Topology, Springer-verlag, 2005.
[4] J.R. Munkres, Topology, Second Edition, Pearson Education, 2003.
[5] T. B. Singh, Elements of Topology, CRC Press, 2013.
[6] S. Willard, General Topology, Dover Publications, Inc. N.Y., 2004.

Math14-304(A): Coding Theory

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, Bounds on minimum distance for block codes, Plotkin bound, Hamming sphere packing bound, Varshamov-Gilbert-Sacks bound.

Bounds for burst-error detecting and correcting codes, Important linear block codes, Hamming codes.

Golay codes, Perfect codes, Quasi-perfect codes, Reed-Muller codes, Codes derived from Hadamard matrices, Product codes, Concatenated codes.

Text book(s).

[1] W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes. M.I.T. Press, Cambridge, Massachusetts, 1972.

Reference books.

[1] Raymond Hill, A First Course in Coding Theory, Oxford University Press, 1990.
[2] Man Young Rhee, Error Correcting Coding Theory, McGraw Hill Inc., 1989.
[3] F.J. Macwilliams and N.J. A. Sloane, The Theory of Error Correcting Codes, North- Holland, 2006.

Math14-304(b): Computational Fluid Dynamics

Mathematical description of the physical phenomena. Governing equations-mass, momentum, energy, species. General form of the scalar transport equation, Elliptic, parabolic and hyperbolic equations. Basics of discretization methods: explicit and implicit approaches. Methods for deriving discretization equations by finite differences to one-dimensional and two-dimensional parabolic, elliptic and hyperbolic equations. Schmidt, Dufort-Frankel, Lax-Wendroff, Crank-Nicolson and ADI methods.

Methods for solving discretized equations. Accuracy, stability and convergence of the finite difference methods. Methods for deriving discretization equations by finite volume methods. Convection and Diffusion- Steady one-dimensional convection and diffusion, upwind, exponential, hybrid, power, QUICK schemes.

Two-dimensional convection-diffusion, accuracy of upwind scheme; false diffusion and dispersion, boundary conditions. Flow field calculation, pressure-velocity coupling, vorticity-stream function formulation, staggered grid, SIMPLE, SIMPLER and PISO algorithms.

Finite volume methods for unsteady flows; One-dimensional unsteady heat conduction, implicit method for two-dimensional problem. Discretization of transient convection-Diffusion equation.

Text book(s).

[1] D.A. Anderson J.C. Tannehill and Richard H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor and Francis, Hemisphere Pub. Comp., USA, 1997.

Reference books.

[1] John D. Anderson, Computational Fluid Dynamics, McGraw-Hill, 1995.
[2] S. V. Patankar, Numerical Heat Transfer and Fluid Flow, Taylor and Francis, Hemisphere Pub. Comp., USA, 2004.
[3] H.K.Versteeg, and W.Malalasekera , An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson, 2007.
[4] T.J. Chung, Computational Fluid Dynamics, Cambridge Univ.Press, Newyork, USA, 2002.

Math14-304(c): Computational Methods for ODEs

Initial Value Problems (IVPs) for the system of ordinary differential equations (ODEs); Difference equations; Numerical Methods; Local truncation errors; global truncation error; Stability analysis; Interval of absolute stability; Convergence and consistency.

Single-step Methods: Taylor series method; Explicit and Implicit Runge-Kutta methods and their stability and convergence analysis; Extrapolation method; Runge-Kutta method for the second order ODEs and Stiff-system of differential equations.

Multi-step Methods: Explicit and Implicit multi-step methods; General linear multi-step methods and their stability and convergence analysis; Adams-Moulton method; Adams-Bashforth method; Nystorm method; Multi-step methods for the second order IVPs.

Boundary Value Problems(BVPs): Two point non-linear BVPs for second order ordinary differential equations; Finite difference methods; Convergence analysis; Difference scheme based on quadrature formula; Difference schemes for linear eigen value problems; Mixed boundary conditions; Finite element methods; Assemble of element equations; Variational formulation of BVPs and their solutions; Galerikin method; Ritz method; Finite element solution of BVPs;

Note: Use of scientific calculator is allowed in theory examination

Credit hours: 04 Theory + 02 practical per week.

Text book(s).

[1] J.C. Butcher, Numerical Methods for Ordinary Differential Equations, John Wiley & Sons, New York, 2003.

Reference books.

[1] J.D. Lambert, Numerical Methods for Ordinary Differential Systems: The Initial Value Problem, John Wiley and Sons, New York, 1991.
[2] K. Atkinson, W.Han and D.E. Stewart, Numerical Solution of Ordinary Differential Equations, John Wiley, New York, 2009.

MATH14-304(D): Mathematical Programming

Existence theorems, First order optimality conditions and second order optimality conditions for unconstrained optimization problems, Ekeland's variational principle

Convex functions, Differentiable convex functions, Optimization on convex sets, Separation theorems, Fritz John optimality conditions for constrained nonlinear programming problems, Constraint qualifications, Karush Kuhn Tucker conditions in nonlinear programming, Second order conditions in nonlinear programming

Lagragian saddle points, Duality in nonlinear programming, Strong duality in convex programming, duality for linear and quadratic problems.

Quadratic programming, Wolfe's method as application of Karush Kuhn Tucker conditions, convex simplex method, Penalty function methods.

Text book(s).

[1] Mokhtar S. Bazaraa, Hanif D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, 2006.
[2] Osman Gler, Foundations of Optimization, Springer 2010.
[3] David G. Luenberger and Yinyu Ye, Linear and Nonlinear Programming, Springer, 2008.

Reference books.

[1] Jan Brinkhuis and Vladimir Tikhomirov, Optimization : Insights and Applications, Princeton University Press, 2005.
[2] Kenneth Lange, Optimization, Springer 2013.

MATH14-304(e): Methods of Applied Mathematics

Dimensional analysis, Buckingham Pi Theorem, Scaling, Perturbation methods, regular perturbations, singular perturbations, WKB approximations,

Integral equation: introduction and relation with linear differential equation. Volterra integral equations and its solutions: Method of resolvent kernel, Method of successive approximations. Convolution type of equation: Method of Laplace Transform, System of volterra integral equations, Integro-differential equation. Abel's integral equation and its generalizations.

Fredholm integral equations and its solutions: Method of resolvent kernels, Method of successive approximations. Integral equations with degenerate kernels, Eigen values and eigen functions and their properties, Hilbert Schmidt theorem, Non homogeneous Fredholm integral equation with symmetric kernel, Fredholm alternative.

Variational problems. the variation of a functional and its properties, Extremum of functional, Necessary condition for an extremum, Euler's equation and its generalization, the variational derivative, General variation of a functional and variable end point problem, sufficient conditions for the extremum of a functional.

Text book(s).

[1] M.L. Krasnov, Problems and exercises integral equations, Mir Publication Moscow, 1971
[2] M. Gelfand and S.V. Fomin, Calculus of variations, Prentice Hall, Inc., 2000.

[3] D. Logan: Applied mathematics: A contemporary approach, John Wiley and Sons, New York, 1997.

Reference books.

[1] F.B. Hildebrand, Methods of applied mathematics, Dover Publication, 1992.

MATH14-304(F): Graph Theory

Graphs: Vertices of graphs, Walks and connectedness, Degrees, Operations on graphs, Blocks, Cut-points, bridges and blocks, Block graphs and cut-point graphs

Trees: Elementary properties of trees, Centers and Centroids, Block-cut point trees, Independent cycles and cocycles

Connectivity and Traversability: Connectivity and line connectivity, Menger's theorems, Eulerian graph, Hamiltonian graphs

Planarity and Coloring: Planar graphs, outer planar graphs, Kuratowski's theorem, dual graphs, chromatic number, five color theorem

Text book(s).

[1] F. Harary, Graph theory, Narosa Publishing House, New Delhi, 1988.

Reference books.

[1] R. Balakrishnan and K. Renganathan, A textbook of Graph theory, Springer, 2000
[2] Bela Bollobas, Modern Graph Theory Springer, 2002
[3] G. Chartrand, L. Lesniak, Graphs & digraphs. Fourth edition. Chapman & Hall/CRC, 2005.
[4] Robin J. Wilson, Introduction to Graph Theory (4th Edition), Addison Wesley, 1996

Semester IV

MATH14-401(A): Algebraic Number Theory

Algebraic Numbers, Conjugates and Discriminants, Algebraic Integers, Integral Bases, Norms and Traces, Rings of Integers, Quadratic Fields, Cyclotomic Fields.

Trivial Factorizations, Factorization into Irreducibles, Examples of Non-Unique Factorization into Irreducibles, Prime Factorization, Euclidean Domains, Euclidean Quadratic Fields, Consequences of Unique Factorization, The Ramanujan-Nagell Theorem, Prime Factorization of Ideals.

The Norm of an Ideal, Nonunique Factorization in Cyclotomic Fields, Lattices, The Quotient Torus, Minkowski's Theorem, The Two-Squares Theorem, The-Four Squares Theorem, The Space Lst

The Class-Group, An Existence Theorem, Finiteness of the Class-group, How to Make an Ideal Principal, Unique Factorization of Elements in an Extension Ring, Factorization of a Rational Prime, Minkowski's Constants, Some Class-Number Calculations.

Text book(s).

[1] I. N. Stewart and D. O. Tall, Algebraic Number Theory, Chapman and Hall, London, 1987.

Reference books.

[1] K. Ireland and M. Rosen, A Classical Introduction to Modern Number Theory, Springer-Verlag, 1990.
[2] S. Lang, Algebraic Number Theory, Springer-Verlag, New York Inc., 1994.
[3] D. A. Marcus, Number Fields, Springer-Verlag, New York Inc., 1987.

MATH14-401(B): Theory of Non-Commutative Rings

Basic terminology and examples: simple rings, Dedekind-finite rings, opposite rings, rational quaternions, rings with generators and relations: polynomial rings in commuting variables, group and semi group ring, formal power series ring with pairwise commuting variables or otherwise, division ring of formal Laurent series, hilbert's twist, differential polynomial rings, triangular rings, example of one-sided Noetherian, Artinian rings, semisimple rings, structure of semisimple rings, Wedderburn-Artin's theorem, structure theorem of simple Artinian rings, Constructions of Non-Artin simple rings using skew polynomial and skew Laurentz polynomial, Jacobson radical, prime radical, Jacobson semi simple rings, Hopkins Levitzki theorem, Von Newmann regular rings, prime and semiprime rings,

structure of primitive rings, density theorem, direct products, subdirect sums, commutativity theorems, local rings and semi-local rings.

Text book(s).

[1] T. Y. Lam, A first course in Non-Commutative Rings, Springer-Verlag, 1991.

Reference books.

[1] I. N. Herstein, A First Course in Non-commutative Rings, Carus Monographs of AMS, 1968.
[2] Louis H. Rowen, Ring Theory, Academic Press, 1991.
[3] T. W. Hungerford, Algebra, Springer-Verlag, New York, 1981.

MATH14-401(c): Simplicial Homology Theory

Geometric simplexes, geometric complexes and polyhedra. Simplicial maps, barycentric subdivision, simplicial approximation of continuous maps, contiguous maps. Orientation of geometric complexes, homology groups. Computation of homology groups, the homology of n-sphere. The structure of homology groups, the chain complexes, chain mappings, chain derivation, chain homotopy. The homomorphism induced by continuous maps between two polyhedra. Functorial property of induced homomorphisms, Topological invariance of homology groupsThe degree of self mappings of S^n. The Brower's fixed point theorem, Brower's degree Theorem, Euler-Poincare theorem, Euler's formula, Lefschetz fixed point theorem. Existence of eigen value, Relative homology groups. Invariance of dimension.

Reference books.

[1] H Agoston, Algebraic Topology, Marcel Dekker, 1976.
[2] M A Armstrong,Basic Topology, Springer-Verlag, 1983.
[3] F H Croom,Basic concepts of Algebraic Topology,1976.
[4] S. Deo, Algebraic Topology, A primer, Hindustan Book Agency (2006).

MATH14-301(d): Advanced Group Theory

Normal series, composition series Zessenhaus lemma, Schreier's refinement theorem, Jordan-Holder theorem. Solvable groups, derived series, supersolvable groups, minimal normal subgroup, Hall's theorem, Hall subgroup,

p-complements, central series, nilpotent groups, Schur's theorem, Fitting subgroup, Jacobi identity, Three subgroup lemma, Frattini subgroup, Burnside basis theorem.

Fitting's lemma, Krull-Schmidt theorem, extension of a group, semidirect products, Schur-Zassenhaus lemma, Burnside normal complement theorem and its consequences.

Free group, generators and relations, Fundamental groups of complexes, Tietze's theorem, Covering complexes, Coset enumeration. Free products, Kurosh theorem, free product with amalgamation.

Text book(s).

[1] J. J. Rotman. An introduction to the theory of groups, Springer-Verlag, New York, 1995.

Reference books.

[1] T. W. Hungerford, Algebra, Springer-Verlag, New York, 1981.
[2] D. J. S. Robinson, A course in the theory of groups, Springer-Verlag, New York, 1996.
[3] J. S. Rose, A course on group theory, Dover Publication, New york, 1994.
[4] M. Suzuki, Group theory-I, Springer-Verlag, Berlin, 1982.

MATH14-402(A): Abstract Harmonic Analysis

Introduction to representation theory of involutive Banach algebra, unitary representation of locally compact groups, Gelfand-Raikov theorem.

Representation of some special groups $SU(2)$, Lorentz group, the group of linear transformations of $\mathbb{R}$, unitary representation of compact groups, Schur's lemma, the orthogonality relations.

Characters of finite dimensional representations, Weyl-Peter theorem, convolution of bounded regular complex measures.

The convolution of Banach algebra $M(G)$, Fourier-Stieltjes transform, positive definite functions, Bochner's theorem.

Text book(s).

[1] E. Hewitt and K.A. Ross, Abstract Harmonic Analysis, Vol I, Springer-Verlag, 1993.

Reference books.

[1] J. M. G. Fell and R. S. Doran, Representation of * algebras, Locally Compact groups and Banach * Algebraic Bundles Vol I, II, Academic Press, 1988.
[2] G. B. Folland, A Course in Abstract Harmonic Analysis, CRC Press, 1995.
[3] W. Rudin, Fourier Analysis on Groups, Interscience Publisher, 1990.

MATH14-402(B): Frames and Wavelets

Finite frames, canonical reconstruction formula, frames and matrices, similarity and unitary equivalence of frames, frame bounds and frame algorithms.

Frames and Bessel sequences in infinite dimensional Hilbert spaces, frame sequence, the Gram matrix. Frames and operators, characterization of frames, dual frames, tight frames, continuous frames, frames and signal processing.

Riesz bases, Frames versus Riesz bases, conditions for a frame being a Riesz basis, frames containing a Riesz basis. Bases in Banach spaces, Limitations of bases.

Wavelets, Haar wavelets, basic properties of the Haar scaling function, Haar decomposition and reconstruction algorithms. The Daubechies wavelets, wavelet bases, scaling function.

Text book(s).

[1] O. Christensen, An introduction to frames and Riesz bases, Birkhaüser (2003)
[2] S. Mallat, A wavelet tour of signal processing, Academic Press (2009).

Reference books.

[1] D. Han, K. Kornelson, D. Larson and E. Weber, Frames for undergraduates, Student Math. Lib., (AMS) Vol. 40 (2007).

[2] A. Boggess and F. J. Narcowich, A first course in wavelets with Fourier analysis, Wiley (2009).
[3] D. F. Walnut, Wavelet analysis, Birkhaüser (2002)

MATH14-402(c): Operators on Hardy-Hilbert Spaces

The Hardy Hilbert Space: Basic Definitions and properties.

The unilateral shift and factorisation of Spectral structure. functions: Shift operators, Invariant and reducing subspaces. Inner and outer factorisation, Blaschke factors, singular inner functions, outer functions.

Toeplitz operators: Basic properties of Toeplitz operators,spectral structure.

Hankel operators: Bounded Hankel operators, Hankel operators of finite rank, Compact Hankel operators, self adjointness and normality of Hankel operators. Relation between Hankel and Toeplitz operators.

Text book(s).

[1] R.A. Martinez-Avedano and P. Rosenthal, An Introdution to the Hardy Hilbert Space, Graduate Texts in Mathematics 237, Springer, 2007.

Reference books.

[1] R.G. Douglas, Banach Algebra Techniques in Operator Theory, Graduate Texts in Mathematics 179, Springer, 1998
[2] N.K. Nikolskii, Operators, Functions and Systems: An Easy Reading, Volume 1, Mathematical Surveys and Monographs 92, American Mathematical Society, 2002.

MATH14-402(d): Theory of Unbounded Operators

Unbounded linear operators and their Hilbert Adjoints, Hellinger-Toeplitz Theorem, Hermitian, symmetric and self-adjoint linear operators.

Closed linear operators, closable operators and their closures on Banach spaces, Cayley transform, definciency indices.

Spectral properties of self-adjoint operators; Multiplication and differentiation operators and their spectra.

Semigroup of bounded linear operators: Uniformly continuous and Strongly continuous semigroups, generator of a semigroup, Hille-Yosida Theorem. Dissipative operators, Lumer-Phillip Theorem, properties of dissipative operators. Group of bounded linear operators, Stones Theorem.

Text book(s).

[1] E. Kreyszig, Introductory Functional Analysis with Applications,John Wiley and Sons (2001) and A. PAzy, Semigroups of Linear Operators and Applications to Partial Differential Equations, Springer (1983)

Reference books.

[1] S. Goldberg, Unbounded Linear Operators : Theory and Applications, Dover, (2006)
[2] M. Schechter, Principles of Functional Analysis, American Mathematical Society, (2004)

MATH14-403(A): CALCULUS ON $\mathbb{R}^n$

The differentiability of functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, partial derivatives and differentiability, directional derivatives and differentiability, chain rule, mean value theorems, inverse function theorem and implicit function theorem.

Derivatives of higher order, Taylor's formulas with integral reminder, Lagrange's reminder and Peano's reminder; Integration over a k-cell, primitive mappings, partition of unity, change of variables.

Introduction to differential forms on $\mathbb{R}^n$, basic properties of differential forms, differentiation of differential forms, change of variables in differential forms.

Simplexes and chains, integration of differential forms, Stokes' theorem.

Text book(s).

[1] J.R. Munkres, Analysis on Manifolds, Addison Wesley, 1997
[2] W. Rudin, Principles of Mathematical Analysis, 3rd Edition, Mc Graw Hill, 1986

Reference books.

[1] M. Giaquinta and G. Modica, Mathematical Analysis, An introduction to functions of several variables, Birkhauser, 2009
[2] M. Spivak, Calculus on Manifolds: A Modern Approach to Classical Theorems of Advanced Calculus, Westview Press, 1998.

Math14-403(b): Differential Geometry

Graph and level sets, vector fields, the tangent space, surfaces, orientation, the Gauss map, geodesics, parallel transport, the Weingarten map, curvature of plane curves, arc length and line integrals, curvature of surfaces, parametrized surfaces, surface area and volume, surfaces with boundary, the Gauss-Bonnet Theorem.

Reference books.

[1] Wolfgang Kuhnel: Differential Geometry - curves-surfaces- Manifolds. Second Edition, 2006, AMS.
[2] A: Mishchenko and A. Formentko. A course of Differential Geometry and topology) Mir Publishers Moscow, 1988.
[3] Andrew Pressley: Elementary Differential Geometry. SUMS (Springer), 2001 (Ist Indian Repring 2004).
[4] I.A. Thorpe: Elementary Topics in Differential Geometry. Springer, 1979 (Ist Indian Reprint 2004).

MATH403(c): Topological Dynamics

Dynamical Systems: Definition and examples (including real life examples), Orbits, Types of orbits, Topological conjugancy and orbits, Phase Portrait - Graphical Analysis of orbit, Periodic points and stable sets, Omega and alpha limit sets and their properties, Sarkoviskii's Theorem, Dynamics of Logistic Functions, Shift spaces and subshifts, Subshift of finite type and subshift represented by a matrix.

Definition and examples of expansive homeomorphisms, Properties of expansive homeomorphisms, Non-existence of expansive homeomorphism on the unit interval and unit circle, Generators and weak generators, Generators and expansive homeomorphisms, Converging semiorbits for expansive homeomorphisms, Definition and examples of shadowing property, properties of shadowing property, Topological Stability, Anosov maps and topological stability.

Practicals using MATLAB

Reference books.

[1] N. Aoki and K. Hiraide, Topological theory of Dynamical Systems, Recent Advances, North Holland Publications, 1994.

[2] Brin and Stuck, Introduction to Dynamical Systems,, Cambridge Univ. Press, 2002

[3] D. Hanselman and B. Littlefiels, Mastering MATLAB, Pearson Education, 2005.

[4] D. Lind and B. Marcus, Symbolic Dynamics and Coding, Cambridge University Press, 1996.

[5] Clark Robinson, Dynamical Systems, Stability, Symbolic Dynamics and Chaos, CRC Press, 1998.

[6] J. De. Vries, Elements of Topological Dynamics, Mathematics and its applications, Kluwer Academic Publishers, 2000

Math14-404(a): Advanced Coding Theory

Tree codes, Convolutional codes, Description of linear tree and convolutional codes by matrices, Standard array, Bounds on minimum distance for convolutional codes, V-G-S bound, Bounds for burst-error detecting and correcting convolutional codes, The Lee metric, Packing bound for Hamming code w.r.t. Lee metric, The algebra of polynomials, Residue classes, Galois fields, Multiplicative group of a Galois field.

Cyclic codes, Cyclic codes as ideals, Matrix description of cyclic codes, Hamming and Golay codes as cyclic codes, Error detection with cyclic codes, Error-correction procedure for short cyclic codes, Shortended cyclic codes, Pseudo cyclic codes.

Code symmetry, Invariance of codes under transitive group of permutations, Bose-Chaudhary-Hocquenghem (BCH) codes, BCH bounds, Reed-Solomon (RS) codes, Majority-logic decodable codes, Majority-logic decoding.

Singleton bound, The Griesmer bound, Maximum-distance separable (MDS) codes, Generator and parity-check matrices of MDS codes, Weight distribution of MDS code, Necessary and sufficient conditions for a linear code to be an MDS code, MDS codes from RS codes, Abramson codes, Closed-loop burst-error correcting codes (Fire codes), Error locating codes.

Text book(s).

[1] F.J. Macwilliams and N.J. A. Sloane, Theory of Error Correcting Codes, North- Holland Publishing Company, 2006.
[2] W.W. Peterson and E.J. Weldon, Jr., Error-Correcting Codes, M.I.T. Press, Cambridge, Massachusetts, 1972.

Reference books.

[1] E.R. Berlekamp, Algebraic Coding Theory, McGraw Hill Inc., 1984.
[2] W.C. Huffman and V. Pless, The Theory of Error Correcting Codes, CambridgebUniversity Press, 1998.

MATH14-404(B): Advanced Fluid Dynamics

Thermodynamics and dimensional analysis: Equation of state of a substance, First law of Thermodynamics, Internal energy and specific heat of gas, entropy, Second law of thermodynamics. Energy equation, Non-dimensionalizing the basic equations of incompressible viscous fluid flow, Non-dimensional Numbers.

Gas Dynamics: Compressibility effects in real fluids, Elements of wave motion in a gas, Speed of sound, Basic equation of one-dimensional compressible flow, Subsonic, sonic and supersonic flows, Isentropic gas Flow, Flow through a nozzle, Normal shock wave, oblique shock wave and their elementary analysis.

Magnetohydrodynamics: Concept, Maxwell' electromagnetic field equations, Equation of motion of a conducting fluid, MHD approximations, Rate of flow of charge, Magnetic Reynolds number and Magnetic field equation, Alfven's theorem, Magnetic body force, Magnetohydrodynamic Waves.

Boundary layer theory: Concept of Boundary Layer, Boundary layer thickness, Boundary layer equations for two-dimensional incompressible flow, Boundary layer along a flat plate, General properties of the boundary-layer equations: dependence on Reynolds number, similar solutions, Momentum and energy integral equations for the boundary layer.

Text book(s).

[1] Alan Jeffery, Magnetohydrodynamics, Oliver and Boyd Ltd., Edinburgh, 1966
[2] H. Schlichting, K. Gersten, Boundary Layer Theory, Springer, 2000
[3] F. Chorlton, Text Book of Fluid Dynamics, GK Publisher, 2009

Reference books.

[1] P.K.Kundu, I.M.Cohen,Fluid Mechanics, 5th edition, Elsevier Inc., 2012
[2] G.K.Batchelor, Introduction to Fluid Mecanics, Foundation book, New Delhi. 1994
[3] R.W.Fox, P.J.Pritchard, A.T.Mcdonald, Introduction to Fluid Mechanics, John Wiley and Sons, 2010

Math14-404(c): Computational Methods for PDEs

Finite difference methods for 2D and 3D elliptic boundary value problems (BVPs) of second and fourth order approximations; Finite difference approximations to Poissons equation in cylindrical and spherical polar coordinates; Solution of large system of algebraic equations corresponding to discrete problems and iterative methods (Jacobi, Gauss-Seidel and SOR); Alternating direction methods.

Different 2- and 3-level explicit and implicit finite difference approximations to heat conduction equation with Dirichlet and Neumann boundary conditions; Stability analysis, compatibility, consistency and convergence of the difference methods; ADI methods for 2- & 3-D parabolic equations; Finite difference approximations to heat equation in polar coordinates.

Methods of characteristics for evolution problem of hyperbolic type; Von-Neumann method for stability analysis; Operator splitting methods for 2D and 3D wave equations; Explicit and implicit difference schemes for first order hyperbolic equations and their stability analysis; System of equations for first order hyperbolic equations; Conservative form.

Finite element methods for second order elliptic BVPs; Finite element equations; Variational problems; Triangular and rectangular finite elements; Standard examples of finite elements; Mixed finite element methods; Finite element method for parabolic initial and boundary value problems; Semi-discrete and complete discrete schemes; Error estimates and convergence analysis.

Note: Use of scientific calculator is allowed in theory examination

Credit hours: 04 Theory + 02 practical per week.

Text book(s).

[1] J.C. Strickwerda, Finite Difference Schemes & Partial Differential Equations, SIAM publications, 2004.

[2] C. Johnson, Numerical solution of partial differential equations by Finite element methods, Cambridge University Press, 1987.

Reference books.

[1] A. J. Davies, The finite element method: An introduction with partial differential equations, Oxford University Press, 2011.
[2] K. W. Morton, & David Mayers, Numerical solution of partial differential equations, Cambridge University Press, 2005.
[3] J.W.Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Springer and Verlag, Berlin, 1998.
[4] J.W.Thomas, Numerical Partial Differential Equations: Conservation Laws and Elliptic Equations, Springer and Verlag, Berlin, 1999.

Math14-404(d): Cryptography

Secure communications, Shift ciphers, Affine ciphers, Vigenere cipher key, Symmetric key, Public key, Block ciphers, One-time pads, Secure random bit generator, Linear feedback shift register sequences.

Differential cryptanalysis, Modes of DES, Attack on DES, Advanced encryption standard.

RSA, Attacks on RSA, Diffie-Hellman key exchange, ElGamal public key cryptosystem, cryptographic hash function.

RSA signatures, ElGamal signature, Hashing and signing, Digital signature algorithm.

Text book(s).

[1] Johannes A. Buchmann, Introduction to Cryptography, Springer 2000.

Reference books.

[1] Douglas Robert Stinson, Cryptography - Theory and Practice, Chapman Hall / CRC 2006.
[2] Wade Trappe and Lawrence C. Washington, Introduction to Cryptography with Coding Theory, Pearson Prentice Hall, 2006.

Math14-404(e): Dynamical Systems

Review of stability for linear systems. Flow defined by nonlinear systems of ODEs, linearization and stable manifold theorem. Hartman-Grobman theorem. Stability and Lyapunov functions. Saddle point, nodes, foci, centers and nonhyperbolic critical points. Gradient and Hamiltonian systems.

Limit sets and attractors. Poincare map, Poincare Benedixson theory and Poincare index Theorem. Structural stability and Peixoto's theorem, Bifurcation at non-hyperbolic equilibrium points.

Reference books.

[1] V.I. Arnold, Ordinary Differential Equations, rentice Hall of India, New Delhi, 1998.
[2] M.W. Hirsch and S. Smale, Differential Equations, Dynamical Systems and inear Algebra, Academic Press, NY, 174.
[3] L. Perko, Differential Equations and Dynamical Systems, Springer Verlag, NY, 1991.
[4] S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos, TAM Vol.2, Springer-Verlag, NY, 1990.
[5] Richard Holmgren, A First Course in Discrete Dynamical Systems, Springer-Verlag, NY, 1994.

MATH14-404(f): Optimization Technique and Control Theory

Extended real valued functions, Proper convex functions, Subgradients, Directional derivatives.

Conjugate functions, Dual convex programs, Optimality conditions and Lagrange multipliers, Duality and optimality for standard convex programs, Gradient descent method, Gradient projection method.

Newton's method, Conjugate gradient method, Dynamic programming, Bellman's principle of optimality, Allocation problem, Stage coach problem.

Optimal control problem and formulations, Variational approach to the fixed-time free endpoint problem, Pontryagin's maximum principle, Dynamic programming and Hamilton-Jacobi-Bellman equation.

Reference books.

[1] Mordecai Avriel, Nonlinear Programming: Analysis & Methods, Dover Publications, New York, 2003.

[2] Osman Gler, Foundations of Optimization, Springer 2010.

[3] Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2010.

[4] Daniel Liberzon, Calculus of Variations and Optimal Control Theory: A Concise Introduction, Princeton University Press, 2012.

[5] Jan Brinkhuis and Vladimir Tikhomirov, Optimization : Insights and Applications, Princeton University Press, 2005.

[6] Kenneth Lange, Optimization, Springer 2013.