CURRICULUM
OF
BS MATHEMATICS

(5th Semester Intake)

w.e.f. Spring 2023 & onward

UNIVERSITY OF SARGODHA

This is a BS Mathematics 2-year program (5th semester intake) after 14 years education (BSc/ADS/ADP or equivalent qualification) along with 4 semesters and 68 credit hours.

Eligibility Criteria:

Intake/Admission Criteria	**Eligibility:** At least 45% marks in BSc/ADS/ADP or equivalent qualification with 50% number of courses (credit hours^) of Mathematics and 50% marks in Mathematics courses. **Criteria:** Total marks obtained in BSc/ADS/ADP or equivalent qualification out of 800 marks + Marks obtained in Mathematics courses out of 400 marks + 20 Marks for Hafiz-e-Quran (if applicable).
Total numbers of Credit hours	68
Duration	2 Years
Semester duration	16-18 Weeks
Number of semesters	4 Semesters
Course load per semester	15-18 Credit Hours
Number of courses per semester	5-6 Courses

^The semester rules & regulations will be applied in the deduction of marks (Total marks obtained in BSc/ADS/ADP or equivalent qualification & marks obtained in Mathematics courses).

Assessment Criteria:

Examination	**Marks**
Mid Term	30%
Final Term	50%
Sessional	20%

SCHEME OF STUDIES

Term / Semester-I

MATH-6301	Elements of Set Theory and Mathematical Logic	3(3+0)
MATH-6302	Topology	3(3+0)
MATH-6303	Differential Geometry	3(3+0)
MATH-6304	Ordinary Differential Equations	3(3+0)
MATH-6305	Real Analysis-I	3(3+0)
MATH-6306	Algebra	3(3+0)

Term / Semester-II

MATH-6307	Classical Mechanics	3(3+0)
MATH-6308	Mathematical Methods	3(3+0)
MATH-6309	Complex Analysis	3(3+0)
MATH-6310	Functional Analysis	3(3+0)
MATH-6311	Real Analysis-II	3(3+0)
MATH-6312	Discrete Mathematics	3(3+0)

Term / Semester-III

MATH-6313	Numerical Analysis-I	3(3+0)
MATH-6314	Number Theory	3(3+0)
MATH-6315	Partial Differential Equations	3(3+0)
MATH-6316	Programming Languages for Mathematicains	2(2+0)
MATH-63xx	Elective-I*	3(3+0)
MATH-63xx	Elective-II*	3(3+0)

Term / Semester-IV

MATH-6317	Numerical Analysis-II	3(3+0)
MATH-6318	Integral Equations	3(3+0)
MATH-63xx	Project / Course**	3(3+0)
MATH-63xx	Elective-III*	3(3+0)
MATH-63xx	Elective-IV*	3(3+0)

Total Numbers of Credit Hours=68

* These four courses are optional & can be selected either from list A or B but cannot be mixed from both or any two courses can be selected from list C.

** In lieu of dissertation a course can be selected from list C.

*** Any other language can be added according to availability of resources.

Note: These courses will be offered by the department from the lists of concentration elective courses & free elective courses as per availability of the resources.

List of Concentration Elective Courses

A student must satisfactorily complete 12 credit hours of any one of the following concentration groups of Elective Courses namely, Pure or Applied Mathematics.

List A: Concentration Elective Courses in Pure Mathematics

MATH-6319	Advanced Group Theory-I	3(3+0)
MATH-6320	Advanced Group Theory-II	3(3+0)
MATH-6321	Modern Algebra-I	3(3+0)
MATH-6322	Modern Algebra-II	3(3+0)
MATH-6323	Algebraic Topology-I	3(3+0)
MATH-6324	Algebraic Topology-II	3(3+0)
MATH-6325	Advanced Functional Analysis	3(3+0)
MATH-6326	Theory of Modules	3(3+0)

List B: Concentration Elective Courses in Applied Mathematics

MATH-6327	Electromagnetism-I	3(3+0)
MATH-6328	Electromagnetism-II	3(3+0)
MATH-6329	Fluid Mechanics-I	3(3+0)
MATH-6330	Fluid Mechanics-II	3(3+0)
MATH-6331	Operations Research-I	3(3+0)
MATH-6332	Operations Research-II	3(3+0)
MATH-6333	Quantum Mechanics-I	3(3+0)
MATH-6334	Quantum Mechanics-II	3(3+0)
MATH-6335	Analytical Dynamics	3(3+0)
MATH-6336	Special Relativity	3(3+0)

List C: List of Free Elective Courses

A student must also satisfactorily complete 06 credits of any one of the following free Elective courses in Applied & Pure Mathematics.

MATH-6337	Numerical Solution of Partial differential equations	3(3+0)
MATH-6338	Elasticity Theory	3(3+0)
MATH-6339	History of Mathematics	3(3+0)
MATH-6340	Heat Transfer	3(3+0)
MATH-6341	Bio-Mathematics	3(3+0)
MATH-6342	Theory of Automata	3(3+0)
MATH-6343	Measure Theory	3(3+0)
MATH-6344	Special Functions	3(3+0)
MATH-6345	Theory of Splines-I	3(3+0)
MATH-6346	Theory of Splines-II	3(3+0)
MATH-6347	Methods of Optimization-I	3(3+0)
MATH-6348	Methods of Optimization-II	3(3+0)
MATH-6349	Control Theory	3(3+0)
MATH-6350	Applied Matrix Theory	3(3+0)

Note: Other elective courses can be offered according to availability of resources.

MATH-6301 Elements of Set Theory and Mathematical Logic 3 (3+0)

The main aim of this course is the study of set theory & the concept of mathematical logic. Everything mathematicians do can be reduced to statements about sets, equality & membership which are basics of set theory. This course introduces these basic concepts. The foundational role of set theory & its mathematical development have raised many philosophical questions that have been debated since its inception in the late nineteenth century. The course begins with propositional logic, including two-column proofs and truth table applications, followed by first-order logic, which provides the structure for writing mathematical proofs. Set theory is then introduced and serves as the basis for defining relations, functions, numbers, mathematical induction, ordinals, and cardinals. In particular, mathematicians have shown that virtually all mathematical concepts & results can be formalized within the theory of sets. The course aims at familiarizing the students with cardinals, ordinal numbers, relations, functions, Boolean algebra, fundamentals of propositional & predicate logics.

Contents

1 Set theory: sets, subsets
2 Operations with sets: union, intersection, difference, symmetric difference
3 Cartesian product & disjoint union
4 Functions: graph of a function
5 Composition; injections, surjections, bijections, inverse function
6 Computing cardinals: Cardinality of Cartesian product, union
7 Cardinality of all functions from a set to another set
8 Cardinality of all injective, surjective & bijective functions from a set to another set
9 Infinite sets, finite sets, Countable sets, properties & examples
10 Operations with cardinal numbers. Cantor-Bernstein theorem
11 Relations: equivalence relations
12 Partitions, quotient set; examples
13 Parallelism, similarity of triangles
14 Order relations, min, max, inf, sup; linear order
15 Examples: N, Z, R, P(A). Well ordered sets & induction
16 Inductively ordered sets & Zorn's lemma
17 Mathematical logic: propositional calculus. truth tables
18 Predicate calculus

Recommended Texts

1. Halmos, P. R. (2019). *Native set theory*. New York: Bow Wow Press.
2. Lipschuts, S. (1998). *Schaum's outline of set theory & related topics* (2nd ed.). New York: McGraw-Hill Education.

Suggested Readings

1. Pinter, C. C. (2014). *A book of set theory*. New York: Dover Publication.
2. O'Leary, M. L. (2015). *A first course in mathematical logic & set theory* (1st ed.). New York: Wiley.
3. Smith, D., Eggen, M., & Andre, R.S. (2014). *A transition to advanced mathematics* (8th ed.). New York: Brooks/Cole.

MATH-6302 **Topology** **3(3+0)**

Topology studies continuity in its broadest context. We begin by analyzing the notion of continuity familiar from calculus, showing that it depends on being able to measure distance in Euclidean space. This leads to the more general notion of a metric space. A brief investigation of metric spaces shows that they do not provide the most suitable context for studying continuity. A deeper analysis of continuity in metric spaces shows that only the open sets matter, which leads to the notion of a topological spaces. We easily see that this is the right setting for studying continuity. The central concepts of topology, compactness, connectedness & separation axioms are introduced. Applications of topology to number theory, algebraic geometry, algebra & functional analysis are featured. Since many important applications of topology use metric spaces, we investigate topological concepts applied to them & introduce the notion of completeness. In addition, this course provides the basis for studying differential geometry, functional analysis, classical & quantum mechanics, dynamical systems, algebraic & differential topology.

Contents

1 Topological spaces
2 Bases & sub-bases
3 First & second axiom of countability
4 Separability
5 Continuous functions & homeomorphism
6 Finite product space
7 Separation axioms (T_0)
8 Separation axioms (T_1)
9 Separation axioms (T_2)
10 Techonoff spaces
11 Regular spaces
12 Completely regular spaces
13 Normal spaces
14 Product spaces
15 Compactness
16 Connectedness

Recommended Texts

1. Sheldon, W. D. (2005). *Topology* (1st ed.). New York: McGraw Hill.
2. Willard, S. (2004). *General topology* (1st ed.). New York: Dover Publications.

Suggested Readings

1. Lipschutz, S. (2011). *General topology*, *Schaum's outline series* (1st ed.). New York: McGraw Hill.
2. Armstrong, M.A. (1979). *Basic topology* (1st ed.). New York: McGraw Hill.
3. Mendelson, B. (2009). *Introduction to topology* (3rd ed.). New York: Dover Publications.

MATH-6303 **Differential Geometry** **3(3+0)**

Differential geometry is the study of geometric properties of curves, surfaces, & their higher dimensional analogues using the methods of calculus. It has a long & rich history, &, in addition to its intrinsic mathematical value & important connections with various other branches of mathematics, it has many applications in various physical sciences, e.g., solid mechanics, computer tomography, or general relativity. Differential geometry is a vast subject. This course covers many of the basic concepts of differential geometry in the simpler context of curves & surfaces in ordinary 3-dimensional Euclidean space. The aim is to build both a solid mathematical underst&ing of the fundamental notions of differential geometry & enough visual & geometric intuition of the subject. This course is of interest to students from a variety of math, science & engineering backgrounds, & that after completing this course, the students will ready to study more advanced topics such as global properties of curves & surfaces, geometry of abstract manifolds, tensor analysis, & general relativity.

Contents

1 Space Curves
2 Arc length, tangent
3 Normal & binormal
4 Curvature & torsion of a curve
5 Tangent planes
6 The Frenet-Serret apparatus
7 Fundamental existence theorem of plane curves
8 Four vertex theorem, Isoperimetric inequality
9 Surfaces
10 First fundamental form
11 Isometry & conformal mappings
12 Curves on Surfaces, surface Area
13 Second fundamental form
14 Normal & Principle curvatures
15 Gaussian & Mean curvatures
16 Geodesics

Recommended Texts

1. Somasundaran, D. (2005). *Differential geometry* (1st ed.). New Delhi: Narosa Publishing House.
2. Pressley, A. (2001). *Elementary differential geometry* (1st ed.). New York: Springer-Verlag.

Suggested Readings

1. Wilmore, T. J. (1959). *An introduction to differential geometry* (1st ed.). Oxford Calarendon Press.
2. Weatherburn, C. E. (2016). *Differential geometry of three dimensions*. Cambridge University Press.
3. Millman, R. S., & Parker, G. D. (1977). *Elements of differential geometry*. Englewood Cliffs: Prentice Hall.

MATH-6304 **Ordinary Differential Equations** **3(3+0)**

This course introduces the theory, solution, & application of ordinary differential equations. Topics discussed in the course include methods of solving first-order differential equations, existence & uniqueness theorems, second-order linear equations, power series solutions, higher-order linear equations, systems of equations, non-linear equations, Sturm-Liouville theory, & applications. The relationship between differential equations & linear algebra is emphasized in this course. An introduction to numerical solutions is also provided. Applications of differential equations in physics, engineering, biology, & economics are presented. The goal of this course is to provide the student with an underst&ing of the solutions & applications of ordinary differential equations. The course serves as an introduction to both nonlinear differential equations & provides a prerequisite for further study in those areas.

Contents

1 Introduction to differential equations: Preliminaries & classification of differential equations
2 Verification of solution, existence of unique solutions, introduction to initial value problems
3 Basic concepts, formation & solution of first order ordinary differential equations
4 Separable equations, linear equations, integrating factors, Exact Equations
5 Solution of nonlinear first order differential equations by substitution, Homogeneous Equations,
6 Bernoulli equation, Ricaati's equation & Clairaut equation
7 Modeling with first-order ODEs: Linear models, Nonlinear models
8 Higher order differential equations: Initial value & boundary value problems
9 Homogeneous & non-homogeneous linear higher order ODEs & their solutions, Wronskian,
10 Reduction of order, homogeneous equations with constant coefficients,
11 Nonhomogeneous equations, undetermined coefficients method, Superposition principle
12 Annihilator approach, variation of parameters, Cauchy-Euler equation,
13 Solving system of linear differential equations by elimination
14 Solution of nonlinear differential equations
15 Power series, ordinary & singular points & their types, existence of power series solutions
16 Frobenius theorem, existence of Frobenius series solutions
17 The Bessel, Modified Bessel, Legendre & Hermite equations & their solutions
18 Sturm-Liouville problems: Introduction to eigen value problem, adjoint & self-adjoint operators,
19 Self-adjoint differential equations, eigen values & eigen functions
20 Sturm-Liouville (S-L) boundary value problems, regular & singular S-L problems

Recommended Texts

1 Boyce, W. E., & Diprima, R. C. (2012). *Elementary differential equations & boundary value problems* (10th ed.) USA: John Wiley & Sons.
2 Zill, D.G., & Michael, R. (2009) *Differential equations with boundary-value problems* (5th ed.) New York: Brooks/Cole.

Suggested Readings

1 Arnold, V. I. (1991). *Ordinary differential equations* (3rd ed.). New York: Springer.
2 Apostol, T. (1969). *Multi variable calculus & linear algebra* (2nd ed.). New York: John Wiley & sons.

MATH-6305 **Real Analysis –I** **3(3+0)**

This is the first part of a two-semester course. This course covers the fundamentals of mathematical analysis: convergence of sequences & series, continuity, differentiability, Riemann integral, sequences & series of functions, uniformity, & the interchange of limit operations. It shows the utility of abstract concepts & teaches an underst&ing & construction of proofs. It develops the fundamental ideas of analysis & is aimed at developing the student's ability to describe the real line as a complete, ordered field, to use the definitions of convergence as they apply to sequences, series, & functions, to determine the continuity, differentiability & integrability of functions defined on subsets of the real line, to write solutions to problems & proofs of theorems that meet rigorous st&ards based on content, organization & coherence, argument & support, & style & mechanics, to determine the Riemann integrability of a bounded function & prove a selection of theorems concerning integration, to recognize the difference between pointwise & uniform convergence of a sequence of functions & to illustrate the effect of uniform convergence on the limit function with respect to continuity, differentiability, & integrability.

Contents

1 Number Systems: Ordered fields
2 rational, real & complex numbers
3 Archimedean property
4 supremum, infimum & completeness
5 Topology of real numbers
6 Convergence, completeness, completion of real numbers
7 Heine Borel theorem
8 Sequences & Series of Real Numbers
9 Limits of sequences, algebra of limits
10 Bolzano Weierstrass theorem, Cauchy sequences, liminf, limsup
11 limits of series, convergences tests, absolute & conditional convergence, power series
12 Continuity: Functions, continuity & compactness, existence of minimizers & maximizers
13 uniform continuity, continuity & connectedness, intermediate mean value theorem
14 monotone functions & discontinuities
15 Differentiation: Mean value theorem, L'Hopital's Rule, Taylor's theorem

Recommended Texts

1. Bartle, R. G., & Sherbert, D. R. (2011). *Introduction to real analysis* (4th ed.) New York: John Wiley & Sons.
2. Trench, W. F. (2013). *Introduction to real analysis* (2nd ed.). New Jersey: Prentice Hall.

Suggested Readings

1. Folland, G.B. (1999). *Real analysis* (2nd ed.). New York: John Wiley & Sons.
2. Rudin, W. (1976). *Principles of mathematical analysis* (3rd ed.) New York: McGraw-Hill.
3. Royden, H., & Fitzpatrick, P. (2010). *Real analysis* (4th ed.). New Jersey: Pearson Hall.

MATH-6306 **Algebra** **3(3+0)**

This course is an introduction to group and ring theory. The philosophy of this subject is that we focus on similarities in arithmetic structure between sets (of numbers, matrices, functions or polynomials for example) which might look initially quite different but are connected by the property of being equipped with operations of addition and multiplication. Much of the activity that led to the modern formulation of ring theory took place in the first half of the 20th century. Ring theory is powerful in terms of its scope and generality, but it can be simply described as the study of systems in which addition and multiplication are possible. The objectives of the course are to introduce students to the basic ideas & methods of modern algebra & enable them to underst& the idea of a ring & an integral domain, & be aware of examples of these structures in mathematics; appreciate & be able to prove the basic results of ring theory; The topics covered include ideals, quotient rings, ring homomorphism, the Euclidean algorithm & the principal ideal domains.

Contents

1 Groups, sub-groups, cyclic groups, permutations groups
2 Rings: Definition, examples. Quadratic integer rings
3 The Hamilton quaternions
4 Polynomial rings
5 Matrix rings. Units, zero-divisors
6 Nilpotents, idempotents. Subrings, Ideals
7 Maximal & prime Ideals. Left, right & two-sided ideals; Operations with ideals
8 The ideal generated by a set. Quotient rings. Ring homomorphism
9 The isomorphism theorems, applications
10 Finitely generated ideals
11 Rings of fractions
12 Integral Domain: The Chinese remainder theorem. Divisibility in integral domains
13 Greatest common divisor, least common multiple
14 Euclidean domains, the Euclidean algorithm, Principal ideal domains
15 Prime & irreducible elements in an integral domain
16 Gauss lemma, irreducibility criteria for polynomials

Recommended Texts

1. Gallian, J. A. (2017). *Contemporary Abstract algebra* (9th ed.) New York: Brooks/Cole.
2. Malik D. S., & Mordeson J. N., & Sen M. K. (1997). *Fundamentals of abstract algebra* (1st ed.). New York: WCB/McGraw-Hill.

Suggested Readings

1. Roman, S. (2012). *Fundamentals of group theory* (1st ed.). Switzerland: Birkhäuser Basel.
2. Rose, J. (2012). *A course on group theory*. New York: Dover Publications.
3. Fraleigh, J. B. (2003). A *first course in abstract algebra* (7th ed.). New York: Pearson.

MATH-6307 **Classical Mechanics** **3(3+0)**

The purpose of this course is to provide solid underst&ing of classical mechanics & enable the students to use this underst&ing while studying courses on quantum mechanics, statistical mechanics, electromagnetism, fluid dynamics, space-flight dynamics, astrodynamics & continuum mechanics. The course aims at familiarizing the students with the dynamics of system of particles, kinetic energy, motion of rigid body, Lagrangian & Hamiltonian formulation of mechanics. At the end of this course the students will be able to underst& the fundamental principles of classical mechanics, to master concepts in Lagrangian & Hamiltonian mechanics important to develop solid & systematic problem solving skills. To lay a solid foundation for more advanced study of classical mechanics & quantum mechanics.

Contents

1 Work, power, kinetic energy & energy principle
2 conservative force fields, conservation of energy theorem, impulse
3 Conservation of linear & angular momentum
4 Time varying mass systems (Rockets)
5 Introduction to rigid bodies
6 Translations & rotations
7 Linear & angular velocity of a rigid body about a fixed axis
8 Angular momentum for n particles
9 Rotational kinetic energy
10 Moments & products of inertia
11 Parallel & perpendicular axes theorem
12 Principal axes & principal moments of inertia. Determination of principal axes by diagonalizing the inertia matrix
13 Equimomental systems
14 Coplanar distribution
15 Rotating axes theorem
16 Euler;s dynamical equations of motion. Free rotation of a rigid body with three different principal moments, torque free motion of a symmetrical top
17 The Eulerian angles, angular velocity & kinetic energy in terms of Euler angles

Recommended Texts

1 DiBenedetto, E. (2011). *Classical mechanics: Theory & mathematical modeling*. Basel: Birkhauser.
2 Aruldhas, G. (2016). *Classical mechanics.* Dehli: PHI Private limited.

Suggested Readings

1 Spiegel, M. R. (2004). *Theoretical mechanics* (3rd ed.). Boston: Addison-Wesley Publishing Company.
2 Fowles, G. R., & Cassiday, G. L. (2005). *Analytical mechanics* (7th ed.). New York: Thomson Brooks/COLE.
3 Mir, K. L. (2007). *Theoretical mechanics.* Lahore: Ilmi Ketab Khana.

MATH-6308 **Mathematical Methods** **3(3+0)**

Mathematical methods presents an applied mathematics course designed to provide the necessary analytical and numerical background for courses in astrophysics, plasma physics, fluid dynamics, electromagnetism, and radiation transfer. The main objective of this course is to provide the students with a range of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics & engineering. Calculation-oriented mathematics is included in all topics relevant. Systems of linear equations, Gauss-Jordan-elimination, basic matrix algebra, determinants. Limits and continuity, differensiation and integration of functions in one variable, maxima and minima, implicit differensiation and trigonometric functions, related rates, differentials and linearization, L'Hopitals rule, Newton's method and the bisection method. Riemannsums and the fundamental theorem in calculus, integral functions, definite and and indefinite integrals, basic integration techniques, substitution and partial integration, numerical integration by the rectangle and trapezium methods, improper integrals. Area, volume and arc length. Modeling with differential equations, first order separable and linear differential equations, Euler's method, second order linear differential equations with constant coefficients.

Contents

1 Fourier Methods: The Fourier transforms
2 Fourier analysis of the generalized functions
3 The Laplace transforms
4 Hankel transforms for the solution of PDEs & their application to boundary value problems
5 Green’s Functions & Transform Methods: Expansion for Green’s functions
6 Transform methods. Closed form Green’s functions. Perturbation Techniques
7 Perturbation methods for algebraic equations
8 Perturbation methods for differential equations
9 Variational Methods: Euler-Lagrange equations
10 Integr& involving one, two, three & n variables
11 Special cases of Euler-Lagrange’s equations
12 Necessary conditions for existence of an extremum of a functional
13 Constrained maxima & minima

Recommended Texts

1. Powers, D. L. (2005). *Boundary value problems & partial differential equations* (5th ed.). Boston: Academic Press.
2. Boyce, W. E. (2005). *Elementary differential equations* (8th ed.). New York: John Wiley & Sons.

Suggested Readings

1. Brown, J. W., & Churchil, R. V. (2006). *Fourier series & boundary value problems.* New York: McGraw Hill.
2. Snider, A. D. (2006). *Partial differential equations.* New York: Dover Publications Inc.
3. Boyce, W. E. (2005). *Elementary differential equations* (8th ed.). New York: John Wiley & Sons.
4. Krasnov, M. L., Makarenko, G. I., & Kiselev, A. I. (1985). *Problems & exercises in the calculus of variations.* USA: Imported Publications, Inc.

MATH-6309 **Complex Analysis** **3(3+0)**

This is an introductory course in complex analysis, giving the basics of the theory along with applications, with an emphasis on applications of complex analysis & especially conformal mappings. Students should have a background in real analysis (as in the course Real Analysis I), including the ability to write a simple proof in an analysis context. Complex Analysis is a topic that is extremely useful in many applied topics such as numerical analysis, electrical engineering, physics, chaos theory, & much more, & you will see some of these applications throughout the course. In addition, complex analysis is a subject that is, in a sense, very complete. The concept of complex differentiation is much more restrictive than that of real differentiation & as a result the corresponding theory of complex differentiable functions is a particularly nice one.

Contents

1 Introduction: The algebra of complex numbers
2 Geometric representation of complex numbers
3 Polar form of complex numbers
4 Powers & roots of complex numbers
5 Functions of Complex Variables
6 Limit
7 Continuity
8 Differentiable functions, the Cauchy-Riemann equations
9 Analytic functions, entire functions, harmonic functions
10 Elementary functions: The exponential, Trigonometric functions
11 Hyperbolic, Logarithmic & Inverse elementary functions
12 Complex Integrals: Contours & contour integrals, antiderivatives, independence of path
13 Cauchy-Goursat theorem, Cauchy integral formula, Lioville's theorem, Morerea's theorem
14 Maximum Modulus Principle
15 Series: Power series, Radius of convergence & analyticity
16 Taylor's & Laurent's series
17 Integration & differentiation of power series, isolated singular points
18 Cauchy's residue theorem with applications
19 Types of singularities & calculus of residues, Zeros & Poles, Mobius transforms
20 Conformal mappings & transformations

Recommended Texts

1 Mathews J. H., & Howell, R.W. (2006). *Complex analysis for mathematics & engineering* (5th ed.). Burlington: Jones & Bartlett Publication.
2 Churchill, R.V., & Brown, J.W. (2013). *Complex variables & applications* (9th ed.). New York: McGraw-Hill.

Suggested Readings

1 Remmert, R. (1998). *Theory of complex functions* (1st ed.). New York: Springer-Verlag.
2 Rudin, W. (1987). *Real & complex analysis* (3rd ed.). New York: McGraw-Hill.

MATH-6310 **Functional Analysis** **3(3+0)**

This course extends methods of linear algebra & analysis to spaces of functions, in which the interaction between algebra & analysis allows powerful methods to be developed. The course will be mathematically sophisticated & will use ideas both from linear algebra & analysis. This is a basic graduate level course that introduces the student to Functional Analysis & its applications. It starts with a review of the theory of metric spaces, the theory of Banach spaces & proceeds to develop some key theorems of functional analysis. Then continuous to linear operators in Banach & Hilbert spaces & to spectral theory of self-adjoint operators with applications to the theory of boundary value problems, & the theory of linear elliptic partial differential equations.

Contents

1 Metric Spaces
2 Convergence
3 Cauchy's sequences & examples
4 Completeness of metric space
5 Completeness proofs
6 Normed linear Spaces, Banach Spaces
7 Equivalent norms
8 Linear operators
9 Finite dimensional normed spaces
10 Continuous & bounded linear operators
11 Linear functional, Dual spaces
12 Linear operator & functional on finite dimensional Spaces
13 Inner product Spaces
14 Hilbert Spaces
15 Conjugate spaces
16 Representation of linear functional on Hilbert space
17 Orthogonal sets
18 Orthonormal sets & sequences
19 Orthogonal complements & direct sum
20 Reflexive spaces

Recommended Texts

1 Kreyszig, E. (1989). *Introduction to functional analysis with applications* (1st ed.). New York: John Wiley & Sons.

Suggested Readings

1 Dunford, N., & Schwartz, J. T. (1958). *Linear operators, part-1 general theory*. New York: Interscience publishers.
2 Balakrishnan, A. V. (1981). *Applied functional analysis* (2nd ed.). New York: Springer-Verlag.
3 Conway, J. B. (1995). *A Course in functional analysis* (2nd ed.). New York: Springer-Verlag.

MATH-6311 **Real Analysis –II** **3(3+0)**

This course is continuation of Real Analysis I, this course will continue to cover the fundamentals of real analysis, concentrating on the Riemann-Stieltjes integrals, Functions of Bounded Variation, Improper Integrals, & convergence of series. Emphasis would be on proofs of main results. The aim of this course is also to provide an accessible, reasonably paced treatment of the basic concepts & techniques of real analysis for students in these areas. This course provides greatly strengthening student's underst&ing of the results of calculus & the basis for their validity the uses of deductive reasoning, increasing the student's ability to underst& definitions, underst& proofs, analyze conjectures, find counter-examples to false statements, construct proofs of true statements & enhancing the student's mathematical communication skills.

Contents

1 The Riemann-Stieltjes Integrals
2 Definition & existence of integrals
3 Properties of integrals
4 Fundamental theorem of calculus & its applications
5 Change of variable theorem, integration by parts
6 Functions of Bounded Variation
7 Definition & examples, properties of functions of bounded variation
8 Improper Integrals: Types of improper integrals
9 Tests for convergence of improper integrals
10 Beta & gamma functions
11 Absolute & conditional convergence of improper integrals
12 Sequences & Series of Functions
13 Power series, definition of pointwise & uniform convergence
14 Uniform convergence & continuity
15 Uniform convergence & differentiation, examples of uniform convergence

Pre-requisite: Real Analysis-I

Recommended Texts

1 Bartle, R. G., & Sherbert, D. R. (2011). *Introduction to real analysis* (4^{th} ed.). New York: John Wiley & Sons.
2 Rudin, W. (1976). *Principles of mathematical analysis* (3^{rd} ed.). New York: McGraw-Hill.

Suggested Readings

1 Folland, G. B. (1999). *Real analysis* (2^{nd} ed.). New York: John Wiley & Sons.
2 Hewitt, E., & Stromberg, K. (1965). *Real & abstract analysis*. New York: Springer-Verlag Heidelberg
3 Lang, S. (1968). *Analysis I*. Boston: Addison-Wesley Publ. Co.

MATH-6312 **Discrete Mathematics** **3(3+0)**

This is an introductory course in discrete mathematics. Discrete Mathematics is study of distinct, un-related topics of mathematics; it embraces topics from early stages of mathematical development & recent additions to the discipline as well. It is the study of mathematical structures that are fundamentally discrete rather than continuous. In contrast to real numbers that have the property of varying "smoothly", the objects studied in discrete mathematics, such as integers, graphs, & statements in logic. The goal of this course is to introduce students to ideas and techniques from discrete mathematics that are widely used in science and engineering. This course teaches the students techniques in how to think logically and mathematically and apply these techniques in solving problems. To achieve this goal, students will learn logic and proof, sets, functions, as well as algorithms and mathematical reasoning. Key topics involving relations, graphs, trees, and formal languages and computability are covered in this course. The present course restricts only to counting methods, relations & graphs. The objective of the course is to inculcate in the students the skills that are necessary for decision making in non-continuous situations.

Contents

1 Counting methods: Basic methods: product
2 inclusion-exclusion formulae
3 Permutations & combinations
4 Recurrence relations & their solutions
5 Generating functions
6 Double counting & its pplications
7 Pigeonhole principle & its applications
8 Relations: Binary relations, n-ary Relations, closures of relations
9 Composition of relations, inverse relation
10 Graphs: Graph terminology
11 Representation of graphs
12 Graphs isomorphism
13 Algebraic methods: the incidence matrix, connectivity
14 Eulerian & Hamiltonian paths, shortest path problem
15 Trees & spanning trees, Complete graphs & bivalent graphs

Recommended Texts

1. Rosen, K. H. (2012). *Discrete mathematics & its applications.* New York: The McGraw-Hill Companies, Inc.
2. Chartr, G., & Zhang, P. (2012). *A first course in graph theory.* New York: Dover Publications, Inc.

Suggested Readings

1. Tucker, A. (2002). *Applied combinatorics.* New York: John Wiley & Sons.
2. Diestel, R. (2010). *Graph theory* (4^{th} ed.). New York: Springer- Verlag

Brigs, N. L. (2003). *Discrete mathematics.* Oxford: Oxford University Press.

MATH-6313 **Numerical Analysis-I** **3(3+0)**

This course is designed to teach the students about numerical methods & their theoretical bases. The course aims at inculcating in the students the skill to apply various techniques in numerical analysis, underst& & do calculations about errors that can occur in numerical methods & underst& & be able to use the basics of matrix analysis. It is optimal to verifying numerical methods by using computer programming (MatLab, Maple, C++, etc.)

Contents

1 Error analysis: Floating point arithmetic, Approximations & errors
2 Methods for the solution of nonlinear equations
3 Bisection method, regula-falsi method, Fixed point iteration method
4 Newton-Raphson method, secant method, error analysis for iterative methods
5 Interpolation & polynomial approximation
6 Forward, backward & centered difference formulae
7 Lagrange interpolation, Newton's divided difference formula
8 Interpolation with a cubic spline, Hermite interpolation, Least squares approximation
9 Numerical differentiation & Integration: Forward, backward & central difference formulae
10 Richardson's extrapolation, Newton-Cotes formulae, Numerical integration
11 Rectangular rule, trapezoidal rule, Simpson's 1/3 & 3/8 rules
12 Boole's & Weddle's rules, Gaussian quadrature
13 Numerical solution of a system of linear equations
14 Direct methods: Gaussian elimination method
15 Gauss-Jordan method; matrix inversion; LU-factorization
16 Doolittle's, Crout's & Cholesky's methods
17 Iterative methods: Jacobi, Gauss-Seidel & SOR
18 Eigen values problems
19 Introduction, Power Method, Jaccobi's Method
20 The use of software packages/ programming languages for above mentioned topics is recommended

Recommended Texts

1. Gerald, C.F., & Wheatley, P.O. (2005). *Applied numerical analysis*. London: Pearson Education, Singapore.
2. Burden, R. L., Faires, J. D., & Burden, A.M. (2015). *Numerical analysis* (10^{th} ed.). Boston: Cengage Learning.

Suggested Readings

1. Philip, J. (2019). *Numerical applied computational programming with case studies* (1^{st} ed.). *New York: Apress.*
2. Khoury, R., & Harder, D.W. (2016). *Numerical methods & modelling for engineering* (1^{st} ed.). London: *Springer.*
3. Antia**,** H.M. (2012). *Numerical methods for scientists & engineers* (3^{rd} ed.). New York: Springer.

MATH-6314 **Number Theory** **3(3+0)**

Number theory (or arithmetic or higher arithmetic in older usage) is a branch of pure mathematics devoted primarily to the study of the integers & integer-valued functions. Integers can be considered either in themselves or as solutions to equations (Diophantine geometry). There are two subfields of number theory. One is Analytical Number Theory and other is Algebraic number theory. The focus of the course is on study of the fundamental properties of integers & develops ability to prove basic theorems. The specific objectives include study of division algorithm, prime numbers & their distributions, Diophantine equations & the theory of congruences. Students will learn about the arithmetic of algebraic number fields. They will learn to prove theorems about integral bases, & about unique factorisation into ideals. They will learn to calculate class numbers, & to use the theory to solve simple Diophantine equations.

Contents

1 Divisibility
2 Euclid's theorem
3 Congruences, Elementary properties
4 Residue classes & Euler's function
5 Linear congruence & congruence of higher degree
6 Congruences with prime moduli
7 The theorems of Fermat
8 Euler & Wilson theorem
9 Primitive roots & indices
10 Integers belonging to a given exponent
11 Composite moduli Indices
12 Quadratic Residues
13 Composite moduli
14 Legendre symbol
15 Law of quadratic reciprocity, The Jacobi symbol
16 Number-Theoretic Functions
17 Mobius function
18 The function [x]
19 Diophantine Equations
20 Equations & Fermat's conjecture for n = 2, n = 4

Recommended Texts

1. Rosen, K.H. (2000). *Elementary number theory & its applications*. (4th ed.). Boston: Addison-Wesley.
2. Apostal, T.M. (2010). *Introduction to analytic number theory* (3rd ed.). New York: Springer.

Suggested Readings

1. Leveque, W. J. (2002). *Topics in number theory*, Volumes I & II. New York: Dover Books.
2. Burton, D. M. (2007). *Elementary number theory*. New York: McGraw-Hill.

MATH-6315 **Partial Differential Equations** **3(3+0)**

Partial Differential Equations (PDEs) are in the heart of applied mathematics & many other scientific disciplines. The beginning weeks of the course aim to develop enough familiarity & experience with the basic phenomena, approaches, & methods in solving initial/boundary value problems in the contexts of the classical prototype linear PDEs of constant coefficients: the Laplace equation, the wave equation & the heat equation. A variety of tools & methods, such as Fourier series/eigenfunction expansions, Fourier transforms, energy methods, & maximum principles will be introduced. More importantly, appropriate methods are introduced for the purpose of establishing quantitative as well as qualitative characteristic properties of solutions to each class of equations

Contents

1 First order PDEs: Introduction, Formation of PDEs, Solutions of PDEs of first order
2 The Cauchy's problem for quasi linear first order PDEs, First order nonlinear equations
3 Special types of first order equations Second order PDEs
4 Basic concepts & definitions, Mathematical problems, Linear operator
5 Superposition, Mathematical models
6 The classical equations, The vibrating string, The vibrating membrane
7 Conduction of heat solids, Canonical forms & variable
8 PDEs of second order in two independent variables with constant & variable coefficients
9 Cauchy's problem for second order PDEs in two independent variables
10 Methods of separation of variables, Solutions of elliptic
11 Parabolic & hyperbolic PDEs in Cartesian & cylindrical coordinates
12 Laplace transform: Introduction & properties of Laplace transform
13 Transforms of elementary functions, Periodic functions, error functions
14 Dirac delta function, Inverse Laplace transform, Convolution Theorem
15 Solution of PDEs by Laplace transform, Diffusion & wave equations
16 Fourier transforms, Fourier integral representation
17 Fourier sine & cosine representation, Fourier transform pair
18 Transform of elementary functions & Dirac delta function, Finite Fourier transforms
19 Solutions of heat, Wave & Laplace equations by Fourier transforms

Recommended Texts

1 Zill, D. G., & Michael, R. (2009). *Differential equations with boundary-value problems* (5th ed.) New York: Brooks/Cole.
2 Polking, J., & Boggess, A. (2005). *Differential equations with boundary value problems* (2nd ed.). London: Pearson.

Suggested Readings

1 Wloka, J. (1987). *Partial differential equations* (1st ed.). Cambridge: Cambridge University Press.
2 Humi, M., & Miller, W. B. (1991). *Boundary value problems & partial differential equations* (1st ed.). Boston: PWS- KENT Publishing Company.

MATH-6316 **Programming Languages for Mathematicians** **2(2+0)**

Programming Languages plays an important role in Mathematics. More often, the act of programming involves problem-solving in itself, where you then take your answers and apply them to build a program. However, mathematicians sometimes require some programming languages for assistance, and some of the best programming languages for math work wonders when you're trying to hone your skills and train yourself in a particular mathematical field. A number of computer software available to deal with mathematical computing & simulation. This course provides a practical introduction to most widely used Mathematical computing software's namely, MATHEMATICA or MAPLE. Maple has a fairly strong advantage when it comes to combinatorial math problems. It's also known for its functional programming constructs, making it extremely interesting to play around with. After this course students will be able to develop computer programs in this software according to their requirements in mathematical computing. It includes ntroduction to data-oriented Python packages, decision trees, support vector machines (SVM), neural networks, and machine learning.

Contents

Mathematica

1 Introduction to the basic environment of MATHMATICA & its syntax
2 Numerical/Algebraic Calculations, vectors, Matrices, Sets, Lists, Tables, arrays
3 Symbolic Mathematics in MATHEMATICA
4 Functions & functional programming
5 Procedural programming, Do, for & while loops, Flow controls
6 Graphics

Maple

1. Introduction to Maple, symbolic computations in MAPLE
2. Vectors, Matrices, Sets, Lists, Tables, arrays & Arrays
3. Operators, Constant, Elementary Functions, Procedures
4. If clauses, selection & conditional execution
5. Looping, for & while loop, looping commands, recursion
6. Graphics

Recommended Texts

1. Wellin, P., Kamin, S., & Gaylord R. (2011). *An introduction to programming with mathematica*, (3rd ed.). Cambridge: Cambridge university press.
2. Monagan, M. B., & Geddes, K. O. (2005). *Maple introductory programming guide*. Waterloo: Maplesoft, a division of Waterloo Maple Inc.

Suggested Readings

1. Aladjev, V. Z., & Bogdivicus, M. A. (2006). *Maple: Programming, physical & engineering Problems*. London: Fultus Publishing.
2. Maeder, R. E. (1997). *Programming in mathematica* (3rd ed.). Boston: Addision-Weseley.
3. Hoste, J. (2009). *Mathematica demystified*. New York: McGraw Hill.

MATH-6317 **Numerical Analysis- II** **3(3+0)**

This course is designed to teach the students about numerical methods & their theoretical bases. The main purpose of this course is to learn the concepts of numerical methods in solving mathematical problems numerically & analyze the error for these methods. The students are expected to know computer programming to be able to write program for each numerical method. Knowledge of calculus & linear algebra would help in learning these methods. The students are encouraged to read certain books containing some applications of numerical methods.

Contents

1 Difference & Differential equation
2 Formulation of difference equations
3 Solution of linear/non-linear difference equations with constant coefficients
4 Solution of homogeneous difference equations with constant coefficients
5 Solution of inhomogeneous difference equations with constant coefficients
6 The Euler method
7 The modified Euler method
8 Runge-Kutta methods
9 Predictor-corrector type methods for solving initial value problems along with convergence
10 Predictor-corrector type methods for solving initial value problems along with instability criteria
11 Runge-Kutta methods for solving initial value problems
12 Predictor-corrector type methods for solving initial value problems.
13 Convergence criteria
14 Instability criteria
15 Finite difference methods
16 Collocation methods for boundary value problems
17 Variational methods for boundary value problems

Pre-requisite: Numerical Analysis-I

Recommended Texts

1. Gerald, C. F., & Wheatley, P.O. (2003). *Applied numerical analysis* (7th ed.). London: Pearson.
2. Balfour, A., & Beveridge, W. T. (1977). *Basic numerical analysis with FORTARAN*. New Hampshire: Heinmann Educational Books Ltd.

Suggested Readings

1. Kuo, Shan S. (1972). *Computer applications of numerical methods*. Islamabad: National Book Foundations.
2. Philip, J. (2019). *Numerical applied computational programming with case studies* (1st ed.). New York: Apress.
3. Khoury, R., & Harder, D.W. (2016). *Numerical methods & modelling for engineering* (1st ed.). London: Springer.
4. Antia, H.M. (2012). *Numerical methods for scientists & engineers* (3rd ed.). New York: Springer.

MATH-6318 **Integral Equations** **3(3+0)**

Many physical problems that are usually solved by differential equation methods can be solved more effectively by integral equation methods. This course will help students gain insight into the application of advanced mathematics & guide them through derivation of appropriate integral equations governing the behavior of several standard physical problems. In addition, a large class of initial & boundary value problems, associated with the differential equations, can be reduced to the integral equations, whence enjoy the advantage of the above integral presentations. This course has many applications in many sciences. This course emphasizes concepts and techniques for solving integral equations from an applied mathematics perspective. Material is selected from the following topics: Volterra and Fredholm equations, Fredholm theory, the Hilbert-Schmidt theorem; Wiener-Hopf Method; Wiener-Hopf Method and partial differential equations; the Hilbert Problem and singular integral equations of Cauchy type; inverse scattering transform; and group theory. Examples are taken from fluid and solid mechanics, acoustics, quantum mechanics, and other applications.

Contents

1 Linear integral equations of the first kind
2 Linear integral equations of the second kind
3 Relationship between differential equation & Volterra integral equation
4 Neumann series
5 Fredholm Integral equation of the second kind with separable Kernels
6 Eigen values, Eigenvectors
7 Iterated functions
8 Quadrature methods
9 Least square methods
10 Homogeneous integral equations of the second kind
11 Fredholm integral equations of the first kind
12 Fredholm integral equations of the second kind
13 Abel's integral equations
14 Hilbert Schmidt theory of integral equations with symmetric Kernels
15 Regularization & filtering techniques

Recommended Texts

1 Jerri, J. (2007). *Introduction to integral equations with applications* (2nd ed.). New York: Sampling Publishing,
2 Wazwaz, A. M. (2011). *Linear & nonlinear integral equations: methods & applications*. New York: Springer.

Suggested Readings

1 Lovitt, W. V. (2005). *Linear integral equations*. New York: Dover Publications.
2 Christian, C., Dale, D., & Hamill, W. (2014). *Boundary integral equation methods & numerical solutions* (1st ed.). New York: Springer.
3 Kanwal, R. P. (1996). *Linear integral equations: theory & technique*. Boston: Birkhauser
4 Tricomi, F. G. (1985). *Integral Equations*. New York: Dover Pub.

MATH-6319 **Advance Group theory-I** **3(3+0)**

This is the first part of the two advance course series of Group Theory. This course aims to introduce students to some more sophisticated concepts & results of group theory as an essential part of general mathematical culture & as a basis for further study of more advanced mathematics. The ideal aim of Group Theory is the classification of all groups (up to isomorphism). It will be shown that this goal can be achieved for finitely generated abelian groups. In general, however, there is no hope of a similar result as the situation is far too complex, even for finite groups. Still, since groups are of great importance for the whole of mathematics, there is a highly developed theory of outst&ing beauty. It takes just three simple axioms to define a group, & it is fascinating how much can be deduced from so little. The course is devoted to some of the basic concepts & results of Group Theory.

Contents

1 Group of automorphisms, inner automorphisms, definition & related results
2 Characteristic & fully invariant subgroups,
3 Symmetric Groups, cyclic permutations
4 Even & odd permutations
5 The alternating groups, conjugacy classes of symmetric & alternating groups
6 Generators of symmetric & alternating groups
7 Simple groups
8 Simplicity of symmetric & alternating groups
9 Group Action on sets or G-sets
10 Orbits & stabilizer subgroups
11 Finite direct products
12 Finitely generated abelian groups
13 P-groups, Sylow's Theorems
14 Application of Sylow's Theorems
15 Linear Groups
16 Types of Linear Groups, Classical Groups

Recommended Texts

1. Rotman, J. J. (1999). *An Introduction to the theory of groups* (4^{th} ed). New York: Springer.
2. Shah, S.K., & Shankar A. G. (2013). *Group theory*. London: Dorling Kindersley.

Suggested Readings

1. Rose, H. E. (2009). *A course on finite groups* (1^{st} ed). New York: Springer-Verlag.
2. Fraleigh, J. B. (2003). A *first course in abstract algebra* (7^{th} ed.). Boston: Addison-Wesley Publishing Company.
3. Malik, D. S., Mordeson J. N., & Sen M. K. (1997). *Fundamentals of abstract algebra*. New York: WCB/McGraw-Hill.
4. Rose, J. A. (2012). *Course on group theory* (Revised ed.). New York: Dover Publications.

MATH-6320 **Advance Group theory-II** **3(3+0)**

This course is the continuation of the course "Advanced Group Theory-1". This course aims to introduce students to some more sophisticated concepts & results of group theory as an essential part of general mathematical culture & as a basis for further study of more advanced mathematics. The ideal aim of Group Theory is the classification of all groups (up to isomorphism). It will be shown that this goal can be achieved for finitely generated abelian groups. This course covers the advanced topics in group theory such as solvable groups, Upper & Lower Central series nilpotent groups & free groups.

Contents

1 Series in groups
2 Normal series
3 Normal series & its refinement
4 Composition series
5 Equivalent composition series
6 Jordan Holder Theorem
7 Solvable groups, definition, examples & related results
8 Upper & Lower Central series
9 Nilpotent groups
10 Characterization of finite nilpotent groups
11 The Frattini subgroups, definition, examples & related results
12 Free groups, definition, examples & related results
13 Free Product, definition, examples & related results
14 Group algebras
15 Representation modules

Pre-requisite: Advance Group Theory-I

Recommended Texts

1. Rotman, J. J. (1999). *An Introduction to the theory of groups* (4th ed). New York: Springer.
2. Shah, S.K., & Shankar A. G. (2013). *Group theory*. London: Dorling Kindersley.

Suggested Readings

1. Rose, H. E. (2009). *A course on finite groups* (1st ed). New York: Springer-Verlag.
2. Fraleigh, J. B. (2003). A *first course in abstract algebra* (7th ed.). Boston: Addison-Wesley Publishing Company.
3. Malik, D. S., Mordeson J. N., & Sen M. K. (1997). *Fundamentals of abstract algebra*. New York: WCB/McGraw-Hill.
4. Rose, J. A. (2012). *Course on group theory* (Revised ed.). New York: Dover Publications.

MATH-6321 **Modern Algebra-I** **3(3+0)**

The word "algebra" means many things. The word dates back about 1200 years ago to part of the title of al-Khwarizmi's book on the subject, but the subject itself goes back 4000 years ago to ancient Babylonia & Egypt. This course introduces concepts of ring theory. The main objective of this course is to prepare students for courses which require a good back ground in Ring theory, Ring Homomorphism, basics Theorem etc. The focus of this course is the study of ideal theory & several domains in ring theory. Homework, graded homework, class quizzes, tests & a final exam will be used to assess the Student Learning Outcomes: Upon successful completion of the course, students will be able to: Demonstrate ability to think critically by interpreting theorems & relating results to problems in other mathematical disciplines. Demonstrate ability to think critically by recognizing patterns & principles of algebra & relating them to the number system. Work effectively with others to discuss homework problems put on the board. This will be assessed through class discussions.

Contents

1 Polynomial rings
2 Division algorithm for polynomials
3 Prime elements
4 Irreducible elements
5 Euclidean domain
6 Principal ideal domain
7 Greatest common divisor
8 Prime & irreducible elements
9 Unique factorization domain
10 Factorization of polynomials over a UFD
11 Irreducibility of polynomials
12 Eisenstein's irreducibility criterion
13 Maximal ideals
14 Prime ideals
15 Primary ideals
16 Noetherian rings
17 Artinian rings

Recommended Texts

1. Gallian, J. A. (2017). *Contemporary abstract algebra* (9th ed). New York: Brooks/Cole.
2. Malik, D. S., Mordeson, J. N., & Sen, M. K. (1997). *Fundamentals of abstract algebra*. New York: WCB/McGraw-Hill.

Suggested Readings

1. Roman, S. (2005). *Field theory (Graduate Texts in Mathematics)* (2nd ed.). New York: Springer.
2. Ames, D. B. (1968). *Introduction to abstract algebra. (*1st ed.). Scranton: Pennsylvania international Textbook Co.

MATH-6322 **Modern Algebra-II** **3(3+0)**

The word “algebra” means many things. The word dates back about 1200 years ago to part of the title of al-Khwarizmi’s book on the subject, but the subject itself goes back 4000 years ago to ancient Babylonia & Egypt. Modern algebra is a cornerstone of modern mathematics. This course introduces concepts of ring & group theory. The main objective of this course is to prepare students for courses which require a good background in Group Theory, Rings, Galois Theory, Symmetric group & permutation group etc. It is assumed that the students possess some mathematical maturity & are comfortable with writing proofs. After completing this course, student will be able to: Define & state some of the main concepts & theorems of Function Analysis. Apply their knowledge of subject in the investigation of examples. Prove basic proportions concerning functional analysis.

Contents

1 Finite & finitely generated Abelian groups
2 Fields
3 Finite fields
4 Field extension
5 Galois theory
6 Galois theory of equations
7 Construction with straight-edge
8 Construction with compass
9 Splitting field of polynomials
10 The Galios groups
11 Some results on finite groups
12 Symmetric group as Galois group
13 Construct able regular n-gones
14 The Galois group as permutation group

Pre-requisite: Modern Algebra-I

Recommended Texts

1. Malik, D. S., Mordeson, J. N., & Sen, M. K. (1997). *Fundamentals of abstract algebra*. New York: WCB/McGraw-Hill.
2. Roman, S. (2005). *Field theory (Graduate Texts in Mathematics) (*2nd ed.). New York: Springer.

Suggested Readings

1. Howie, J. M. (2006). *Fields & galois theory* (2nd ed.). New York: Springer.
2. Northcott, D. D. (1973). *A first course of Homological algebra* (1st ed.). Cambridge: Cambridge University Press.
3. Jacobson, N. (1985). *Basic algebra I* (1st ed.). New York: Freeman & Co.
4. Ames, D. B. (1968). *Introduction to abstract algebra* (1st ed.). Scranton, PA: International Textbook Co.

MATH-6323 Algebraic Topology-I 3(3+0)

The course gives an introduction to algebraic topology, with emphasis on the fundamental group and the singular homology groups of topological spaces. This course aims to understand some fundamental ideas in algebraic topology; to apply discrete, algebraic methods to solve topological problems; to develop some intuition for how algebraic topology relates to concrete topological problems. The primary aim of this course is to explore properties of topological spaces. We shall consider in detail examples such as surfaces. To distinguish topological spaces, we need to define topological invariants, such as the "fundamental group" or the "homology" of a space". To enable us to do this, knowledge of basic group theory & topology is essential. Some background in real analysis would also be helpful. After completing the course students can work with cell complexes and the basic notions of homotopy theory, know the construction of the fundamental group of a topological space, can use van Kampen´s theorem to calculate this group for cell complexes and know the connection between covering spaces and the fundamental group.

Contents

1 Affine spaces
2 Singular theory
3 Chain complexes
4 Homotopy invariance of homology
5 Relation between n, & H
6 Relative homology
7 The exact homology sequences.
8 Nilpotent groups
9 Homotopy theory
10 Homotopy theory of path & maps
11 Fundamental group of circles
12 Covering spaces
13 Lifting criterion
14 Loop spaces
15 Higher homotopy group.
16 Loop spaces
17 Higher homotopy group.

Recommended Texts

1. Adhikari, M. R. (2016). *Basic algebraic topology & its applications* (1st ed.). New York: Springer
2. Hatcher, A. (2001). *Algebraic topology*. Cambridge: Cambridge University Press.

Suggested Readings

1. Greenberg, M. J., & Harper, J. R. (1981). *Algebraic topology: A first course* (1st ed.). Boulder: Westview Press.
2. Croom, F. H. (1978). *Basic concept of algebraic theory.* New York: Spinger-Verlag.
3. Kosniowski, C. A. (1980). *First course in algebraic topology*. Cambridge: Cambridge University Press

MATH-6324 **Algebraic Topology-II** **3(3+0)**

This course is a continuation of Algebraic Topology-I. In this course, the objective is the study of knots, links, surfaces & higher dimensional analogs called manifolds with the underst&ing that continuous deformations do not change objects. So a doughnut (torus) & a coffee mug are essentially the same (homeomorphic) in this course. For example, how does a creature living on a sphere tell that she is not on the plane, on the torus, or perhaps a two holed torus? Can one turn a sphere inside out without creasing it? What would it be like to live inside a three dimensional sphere? Can one continuously deform a trefoil knot to get its mirror image? Can the wind be blowing at every point on the earth at once? Can you tell if a graph is planar? Can you tell if a knot is trivial? Is there a list of all possible two dimensional surfaces? How about three dimensional ones? These are some of the motivating questions for the subject. Algebraic topology attempts to answer such questions by assigning algebraic invariants such as numbers, or groups, to topological spaces. Examples include the Euler number of a surface, the Poincare index of a vector field, the genus of a torus, the fundamental group & more fancy homology groups.

Contents

1 Relative homology
2 The exact homology sequences
3 Excion theorem & application to spheres
4 Mayer Victoris sequences
5 Jordan-Brouwer separation theorem
6 Spherical complexes
7 Betti number
8 Euler characteristic
9 Cell Complexes
10 Adjunction spaces

Pre-requisite: Algebraic Topology-I

Recommended Texts

1. Adhikari, M. R. (2016). *Basic algebraic topology & its applications* (1st ed.). New York: Springer
2. Hatcher, A. (2001). *Algebraic topology*. Cambridge: Cambridge University Press.

Suggested Readings

1. Greenberg, M. J., & Harper, J. R. (1981). *Algebraic topology: A first course* (1st ed.). Boulder: Westview Press.
2. Croom, F. H. (1978). *Basic concept of algebraic theory.* New York: Spinger-Verlag.
3. Kosniowski, C. A. (1980). *First course in algebraic topology*. Cambridge: Cambridge University Press

MATH-6325 **Advanced Functional Analysis** **3(3+0)**

This course is intended both for continuing mathematics students & for other students using mathematics at a high level in theoretical physics, engineering & information technology, & mathematical economics. This course introduces concepts of Fundamental Theorems & Spectral Theory. On satisfying the requirements of this course, students will have the knowledge & skills to explain the fundamental concepts of functional analysis & their role in modern mathematics & applied contexts. Moreover, it demonstrate accurate & efficient use of functional analysis techniques & the capacity for mathematical reasoning through analyzing, proving & explaining concepts from functional analysis. This course will mostly deal with the analysis of unbounded operators on a Hilbert or Banach space with a particular focus on Schrodinger operators arising in quantum mechanics. All the abstract notions presented in the course will be motivated & illustrated by concrete examples. In order to be able to present some of the more interesting material, emphasis will be put on the ideas of proofs & their conceptual underst&ing rather than the rigorous verification of every little detail.

Contents

Fundamental Theorems:

1 Zorn's lemma
2 Statement of Hahn-Banach theorem for real vector spaces
3 Hahn-Banach theorem for complex vector spaces
4 Hahn-Banach theorem for normed spaces
5 Uniform boundedness theorem
6 Open mapping theorem
7 Closed graph theorem

Spectral Theory:

1 Spectral properties of bounded linear operations on Normed Spaces
2 Further properties of Resolvent & spectrum
3 Use of complex Analysis in spectral theory
4 Compact linear operators on Normed Spaces

Recommended Texts

1. Kreyszig, E. (1989). *Introductory functional analysis with applications* (1st ed.). New York: John Wiley.
2. Brown, A.L. (1970). *Elements of functional analysis* (1st ed.). New York: Van Nostrand & Reinhold Company.

Suggested Readings

1. Oden, J. T. (1979). *Applied functional analysis* (1st ed.). New Jersey: Prentice-Hall Inc.
2. Brown, A.L. (1970). *Elements of functional analysis* (1st ed.). New York: Van Nostrand & Reinhold Company.

MATH-6326 **Theory of Modules** **3(3+0)**

This course is an introduction to module theory, who knows something about linear algebra and ring theory. Its main aim is the derivation of the structure theory of modules over Euclidean domains. This theory is applied to obtain the structure of abelian groups and the rational canonical and Jordan normal forms of matrices. The basic facts about rings and modules are given in full generality, so that some further topics can be discussed, including projective modules and the connection between modules and representations of groups. It aims to develop the general theory of rings & then study in some detail a new concept, that of a module over a ring. The theory of rings & module is key to many more advanced algebra courses. This subject presents the foundational material for the last of the basic algebraic structure pervading contemporary pure mathematics, namely fields & modules. The basic definitions & elementary results are given, followed by two important applications of the theory. This course introduces concepts of modules. The main objective of this course is to prepare students for courses which require a good back ground in Modules Theory, Primary component & Invariance Theorem etc.

Contents

1 Elementary notions & examples
2 Modules, sub modules, Quotient modules
3 Finitely generated & cyclic modules, Exact sequences
4 Elementary notions of homological algebra
5 Noetherian rings & modules
6 Artinian rings & modules, Radicals
7 Semisimple rings & modules
8 Tensor product of modules
9 Bimodules
10 Algebra & coalgebra
11 Torsion module
12 Primary components
13 Invariance theorem

Recommended Texts

1. Wang, F., & Kim, H. (2016). *Foundations of commutative rings & their modules* (1st ed.). New York: Springer.
2. Berrick, A. J., & Keating, M. E. (2000). *An introduction to rings & modules: With K-Theory in View* (1st ed.). Cambridge: Cambridge University Press.

Suggested Readings

1. Hartley, B., & Hawkes, T. O. (1980). *Rings, modules & linear algebra (*1st ed.). London: Chapman & Hall.
2. Herstein I. N. (1995). *Topics in algebra with application* (3rd ed.). New York: Books/Cole.
3. Jacobson, N. (1989). *Basic algebra* (2nd ed.). Colorado: Freeman
4. Blyth, T. S. (1977). *Module theory* (1st ed.). Oxford: Oxford University Press.

MATH-6327 **Electromagnetism-I** **3(3+0)**

Electromagnetism is a branch of physics involving the study of the electromagnetic force, a type of physical interaction that occurs between electrically charged particles. The electromagnetic force is carried by electromagnetic fields composed of electric fields & magnetic fields, & it is responsible for electromagnetic radiation such as light. It is one of the four fundamental interactions (commonly called forces) in nature, together with the strong interaction, the weak interaction, & gravitation. At high energy the weak force & electromagnetic force are unified as a single electroweak force. Students will learn properties of coulomb's law, magnetic shells, conductivity & current density vector to flows.

Contents

1 Electrostatics: Coulomb's law
2 Electric field & potential. lines of force & equipotential surfaces
3 Gauss's law & deduction
4 Conductor condensers
5 Dipoles, forces dipoles
6 Dielectrics, polarization & apparent charges
7 Electric displacement
8 Energy of the field, minimum energy
9 Magnetostatic field
10 The magnetostatic law of force, magnetic shells
11 Force on magnetic doublets
12 Magnetic induction, paradia & magnetism
13 Steady & slowly varying currents
14 Electric current
15 Linear conductors
16 Conductivity
17 Resistance
18 Kirchoff's laws
19 Heat production
20 Current density vector
21 Magnetic field of straight & circular current
22 Magnetic flux

Recommended Texts

1. Ferraro, V. C. A. (1956). *Electromagnetic theory* (Revised ed.). London: The Athlon Press
2. Reitz, J. R., Milford, F. J., & Christy, R. W. (1960). *Foundations of electromagnetic theory* (3rd ed.). Boston: Addison-Wesley.

Suggested Readings

1. Pugh, M. E. (196). *Principles of* e*lectricity & magnetism* (1st ed.). Boston: Addison-Wesley.

MATH-6328 **Electromagnetism-II** **3(3+0)**

This course is the continuation of the course Electromagnetism-I. The classical (non-quantum) theory of electromagnetism was first published by James Clerk Maxwell in his 1873 textbook A Treatise on Electricity and Magnetism. A host of scientists during the nineteenth century carried out the work that ultimately led to Maxwell's electromagnetism equations, which is still considered one of the triumphs of classical physics. Maxwell's description of electromagnetism, which demonstrates that electricity and magnetism are different aspects of a unified electromagnetic field, holds true today. Electromagnetism is a branch of physics involving the study of the electromagnetic force, a type of physical interaction that occurs between electrically charged particles. The electromagnetic force is carried by electromagnetic fields composed of electric fields & magnetic fields, & it is responsible for electromagnetic radiation such as light. It is one of the four fundamental interactions (commonly called forces) in nature, together with the strong interaction, the weak interaction, & gravitation. At high energy the weak force & electromagnetic force are unified as a single electroweak force. Students will learn properties of simple introduction to Legendre polynomials, method of images, images in a plane, images with spheres & cylinders.

Contents

1 Vector potential
2 Forces on a circuit in magnetic field
3 Magnetic field energy, Law of electromagnetic induction
4 Co-efficient of self & mutual induction
5 Alternating current & simple I.C.R circuits in series & parallel
6 Power factor, the equations of electromagnetism
7 Maxwell’s equations in free space & material media
8 Solution of Maxwell’s equations
9 Plane electromagnetic waves in homogeneous & isotropic media
10 Reflection & refraction of plane waves
11 Wave guides Laplace’ equation in plane, Polar & cylindrical coordinates
12 Simple introduction to Legendre polynomials
13 Method of images, images in a plane
14 Images with spheres & cylinders

Pre-requisite: Electromagnetism-I

Recommended Texts

3. Ferraro, V. C. A. (1956). *Electromagnetic theory* (Revised ed.). London: The Athlon Press
4. Reitz, J. R., Milford, F. J., & Christy, R. W. (1960). *Foundations of electromagnetic theory* (3rd ed.). Boston: Addison-Wesley.

Suggested Readings

2. Pugh, M. E. (196). *Principles of* electricity *& magnetism* (1st ed.). Boston: Addison-Wesley.

MATH-6329 **Fluid Mechanics-I** **3(3+0)**

This course is the first part of the core level course on fluid mechanics. Fluid mechanics is the branch of physics concerned with the mechanics of fluids (liquids, gases, & plasmas) & the forces on them. It has applications in a wide range of disciplines, including mechanical, civil, chemical & biomedical engineering, geophysics, oceanography, meteorology, astrophysics, & biology. The course of fluid mechanics is introducing fundamental aspects of fluid flow behavior. Students will learn properties of Newtonian fluids; apply concepts of mass, momentum & energy conservation to flows.

Contents

1 Introduction: Definition of Fluid, basics equations
2 Methods of analysis, dimensions & units. Fundamental concepts
3 Fluid as a continuum, velocity field, stress field, viscosity, surface tension, description & classification of fluid motions
4 Fluid Statics: The basic equation of fluid static
5 The st&ard atmosphere
6 Pressure variation in a static fluid
7 Fluid in rigid body motion. Basic equation in integral form for a control volume
8 Basic laws for a system
9 Relation of derivatives to the control volume formulation
10 Conservation of mass
11 Momentum equation for inertial control volume
12 Momentum equation for control volume with rectilinear acceleration
13 Momentum equation for control volume with arbitrary acceleration
14 The angular momentum principle
15 The first law of thermodynamics
16 The second law of thermodynamics
17 Introduction to differential analysis of fluid motion
18 Conservation of mass
19 Stream function for two-dimensional incompressible flow
20 Motion of a fluid element (kinematics), momentum equation

Recommended Texts

1. Fox, R. W., & McDonald, A. T. (2004). *Introduction to fluid mechanics* (6th ed.). New York: John Wiley & Sons.
2. White, F. M. (2006). *Fluid mechanics* (5th ed.). New York: Mc. Graw Hill.

Suggested Readings

1. Granger, R. A. (1985). *Fluid mechanics* (1st ed.). Montana: Winston Publisher.
2. Bruce, R., Rothmayer, A. P., Theodore, H. O., & Wade, W. H. (2013). *Fundamental of fluid mechanics* (7th ed.). New York: Willey Son Publisher.
3. Nakayama, Y. (2018). *Introduction to fluid mechanics* (2nd ed.). Oxford: Butterworh Heinemann Publisher.

MATH-6330 **Fluid Mechanics-II** **3(3+0)**

This course is the seconed part of the core level course on fluid mechanics. Fluid mechanics is concerned with the mechanics of fluids (liquids, gases, & plasmas) & the forces on them. This course covers properties of fluids, laws of fluid mechanics & energy relationships for incompressible fluids Studies flow in closed conduits, including pressure loss, flow measurement, pipe sizing & pump Selection, momentum equation for frictionless flow, Euler's equations, Bernoulli equation- Integration of Euler's equation, laminar flow & Boundary layers.

Contents

1 Incompressible inviscid flow
2 Momentum equation for frictionless flow
3 Euler's equations
4 Euler's equations in streamline coordinates
5 Bernoulli equation- Integration of Euler's equation along a streamline for steady flow
6 Relation between first law of thermodynamics & the Bernoulli equation
7 Unsteady Bernoulli equation-Integration of Euler's equation along a streamline
8 Irrotational flow, internal incompressible viscous flow
9 Fully developed laminar flow
10 Fully developed laminar flow between infinite parallel plates
11 Fully developed laminar flow in a pipe
12 Part-B Flow in pipes & ducts
13 Shear stress distribution in fully developed pipe flow
14 Turbulent velocity profiles in fully developed pipe flow
15 Energy consideration in pipe flow
16 External incompressible viscous flow
17 Boundary layers, the boundary concept, boundary thickness, laminar flat plate
18 Boundary layer: exact solution, momentum, integral equation,
19 Use of momentum integral equation for flow with zero pressure gradient
20 Pressure gradient in boundary-layer flow

Pre-requisite: Fluid Mechanics-I

Recommended Texts

1. Fox, R. W., & McDonald, A. T. (2004). *Introduction to fluid mechanics* (6th ed.). New York: John Wiley & Sons.
2. White, F. M. (2006). *Fluid mechanics* (5th ed.). New York: Mc. Graw Hill.

Suggested Readings

1. Bruce, R., Rothmayer, A. P., Theodore, H. O., & Wade, W. H. (2013). *Fundamental of fluid mechanics* (7th ed.). New York: Willey Son Publisher.
2. Nakayama, Y. (2018). *Introduction to fluid mechanics* (2nd ed.). Oxford: Butterworh Heinemann Publisher.
3. Granger, R. A. (1985). *Fluid mechanics* (1st ed.). Montana: Winston Publisher.

MATH-6331 **Operations Research-I** **3(3+0)**

This course is the 1st part of the course series on operation research. Operations research (OR) is an analytical method of problem-solving & decision-making that is useful in the management of organizations. Operations Research studies analysis and planning of complex systems. In operations research, problems are broken down into basic components & then solved in defined steps by mathematical analysis. The objective of Operations Research, as a mathematical discipline, is to establish theories & algorithms to model & solve mathematical optimization problems that translate to real-life decision-making problems. The purpose of the course is to provide students with the concepts and tools to help them understand the operations research and mathematical modeling methods and to understand different application areas of operations research like transportation problem, assignment model, sequencing models, dynamic programming, game theory, replacement models & inventory models.

Contents

1 Linear Programming
2 Formulation & graphical solution
3 Simplex method, M-technique
4 Two-phase technique
5 Special cases
6 Sensitivity analysis
7 The dual problem
8 Primal dual relationship
9 The dual simplex method
10 Sensitivity
11 Post optimal analysis
12 Transportation model
13 Northwest corner
14 Least cost
15 Vogel's approximation methods
16 The method of multipliers
17 The assignment models
18 The transshipment model
19 Network minimization
20 Shortest route algorithms for variables

Recommended Texts

1. Hamdy, A. T. (2006). *Operations research an introduction* (6th ed.). New York: Macmillan.
2. Gillet, B. E. (1979). *Introduction to operations research* (1st ed.). New York: McGraw Hill.

Suggested Readings

1. Harvy, C. M. (1979). *Operations research*: *A practical introduction* (1st ed.). North Holland: CRC Press
2. Ravindran, A. R. (2008). *Operations research applications* (1st ed.). North Holland: CRC Press.

MATH-6332 **Operations Research-II** **3(3+0)**

Operations research (OR) is an analytical method of problem-solving & decision-making that is useful in the management of organizations. In operations research, problems are broken down into basic components & then solved in defined steps by mathematical analysis. Disciplines that are similar to, or overlap with, operations research include statistical analysis, management science, game theory, optimization theory, artificial intelligence & network analysis. All of these techniques have the goal of solving complex problems & improving quantitative decisions. The objective of Operations Research, as a mathematical discipline, is to establish theories & algorithms to model & solve mathematical optimization problems that translate to real life decision making problems. Students would be able to identify & develop complecated operational research modals from the verbal description of the real system. The underst&ing of the mathematical tools that are needed to solve optimization problems would be increased. They would be analyze the results & propose the theoretical language underst&able to decision making processes in Management Engineering.

Contents

1 Algorithm for cyclic network
2 Maximal flow problems
3 Matrix definition of LP- problems
4 Revised simplex methods
5 Bounded variables decompositions algorithm
6 Parametric linear programming
7 Application of integer programming
8 Cutting plane algorithm
9 Mixed fractional cut algorithm
10 Branch methods
11 Bound methods
12 Zero-one implicit enumeration
13 Element of dynamics programming
14 Problems of dimensionality
15 Solutions of linear program by dynamics programming

Pre-requisite: Operation Research-I

Recommended Texts

1. Hamdy, A. T. (2006). *Operations research an introduction* (6th ed.). New York: Macmillan.
2. Gillet, B. E. (1979). *Introduction to operations research* (1st ed.). New York: McGraw Hill.

Suggested Readings

1. Harvy, C. M. (1979). *Operations research*: *A practical introduction* (1st ed.). North Holland: CRC Press

MATH-6333 **Quantum Mechanics–I** **3(3+0)**

This course is the first part of a two-course sequence., which covered most of the basic topics in quantum mechanics, including perturbation theory, operator techniques, and the addition of angular momentum. Quantum mechanics (QM; also known as quantum physics, quantum theory, the wave mechanical model & matrix mechanics), part of quantum field theory, is a fundamental theory in physics. It describes physical properties of nature on an atomic scale. Classical physics, the description of physics that existed before the theory of relativity & quantum mechanics, describes many aspects of nature at an ordinary (macroscopic) scale, while quantum mechanics explains the aspects of nature at small (atomic & subatomic) scales, for which classical mechanics is insufficient. This course will introduce Dirac's braket formulation of quantum mechanics & make students familiar with various approximation methods applied to atomic, nuclear & solid-state physics, & to scattering.

Contents

1 Inadequacy of classical mechanics
2 Black body radiation, photoelectric effect
3 Compton effect
4 Bohr's theory of atomic structure
5 Wave-particle duality
6 The de-Broglie postulate
7 The uncertainty principle
8 Uncertainty of position
9 Momentum
10 Statement & proof of the uncertainty principle
11 Energy-time uncertainty
12 Eigenvalues & eigen functions
13 Operators & eigen functions
14 Linear operators
15 Operator formalism in quantum mechanics
16 Orthonormal systems
17 Hermitian operators & their properties,
18 Simultaneous eigen functions
19 Parity operators, postulates of quantum mechanics
20 The Schrödinger wave equation
21 Motion in one dimension
22 Step potential, potential barrier, potential well, & harmonic oscillator

Recommended Texts

1. Taylor, G. (1970). *Quantum mechanics* (1st ed.). New South Wales: George Allen & Unwin.
2. Powell, T. L., & Crasemann, B. (1961). *Quantum mechanics* (1st ed.). Boston: Addison Wesley.

Suggested Readings

1. Merzdacker, E. (1988). *Quantum mechanics* (1st ed.). New York: John Wiley.

MATH-6334 **Quantum Mechanics–II** **3(3+0)**

This course is the second part of a two-course sequence. The primary goal of this course is to develop an understanding of some of the more advanced topics and techniques used in quantum mechanics. Most of this material will be essential for graduate research in many areas of physics, such as quantum optics, astrophysics, and atmospheric physics. This course will provide the necessary knowledge and skills to apply advanced techniques in quantum mechanics throughout the students' careers. Quantum mechanics (QM; also known as quantum physics, quantum theory, the wave mechanical model & matrix mechanics), part of quantum field theory, is a fundamental theory in physics. It describes physical properties of nature on an atomic scale. Classical physics, the description of physics that existed before the theory of relativity & quantum mechanics, describes many aspects of nature at an ordinary (macroscopic) scale, while quantum mechanics explains the aspects of nature at small (atomic & subatomic) scales, for which classical mechanics is insufficient. This course is continuation of Quantum Mechanics-I & cover more advance topics.

Contents

1. Motion in three dimensions
2. Angular momentum
3. Commutation relations between components of angular momentum
4. Representation in spherical polar coordinates
5. Simultaneous Eigen functions of Lz & L2
6. Spherically symmetric potential
7. The hydrogen atom
8. Scattering Theory
9. The scattering cross-section
10. Scattering amplitude
11. Scattering equation
12. Born approximation
13. Partial wave analysis
14. Perturbation Theory
15. Time independent perturbation of non-degenerate & degenerate cases
16. Time-dependent perturbations
17. Identical Particle
18. Symmetric & anti-symmetric Eigen function
19. The Pauli exclusion principle.

Pre-requisite: Quantum Mechanics-I

Recommended Texts

1. Taylor, G. (1970). *Quantum mechanics* (1st ed.). New South Wales: George Allen & Unwin.
2. Powell, T. L., & Crasemann, B. (1961). *Quantum mechanics* (1st ed.). Boston: Addison Wesley.

Suggested Readings

1. Merzdacker, E. (1988). *Quantum mechanics* (1st ed.). New York: John Wiley.

MATH- 6335 **Analytical Dynamics** **3(3+0)**

In classical mechanics, analytical dynamics, or more briefly dynamics, is concerned with the relationship between motion of bodies & its causes, namely the forces acting on the bodies & the properties of the bodies, particularly mass & moment of inertia. Analytical dynamics develops Newtonian mechanics to the stage where powerful mathematical techniques can be used to determine the behavior of many physical systems. The mathematical framework also plays a role in the formulation of modern quantum & relativity theories.

Contents

1 Generalized coordinates
2 Constraints
3 Degree of freedom
4 D'Alembert principle
5 Holonomic & non-Holonomic systems, Hamilton's principle
6 Derivation of Lagrange equation from Hamilton's principle
7 Derivation of Hamilton's equation from a variational principle
8 Equations & Examples of Gauge transformations
9 Equations & examples of canonical transformations
10 Orthogonal Point transformations
11 The Principle of Least Action
12 Applications of Hamilton's equation to central force problems
13 Applications to Harmonic oscillator
14 Hamiltonian formulism
15 Lagrange bracket & Poisson brackets with application
16 The Hamilton Jacobi theory, Hamilton Jacobi Theorem
17 The Hamilton Jacobi equation for Hamilton characteristic functions
18 Bilinear co-variant
19 Quasi coordinates
20 Transpositional relations for Quasi coordinate
21 Lagrange's equation for Quasi coordinates
22 Appel's equation for quasi coordinates
23 Whittaker equation with applications
24 Chaplygian system & Chaplygian equation

Recommended Texts

1. Greenwood, D. T. (1965). *Classical dynamics*. New Jersey: Prentice-Hall, Inc.
2. Aruldhas, G. (2016). *Classical mechanics.* New Dehli: PHI Private Limited.
3. Chorlton, F. (1983). *Textbook of dynamics*. Cambridge: E. Horwood.

Suggested Readings

1. Woodhouse, N. M. J. (2009). *Introduction to analytical dynamics* (2nd ed.). New York: Springer-Verlag.
2. Chester, W. (1979). *Mechanics*. London: New South Wales: George Allen & Unwin Ltd.

MATH-6336 **Special Relativity** **3(3+0)**

This course introduces the basic ideas and equations of Einstein's Special Theory of Relativity to understand the physics of Lorentz contraction, time dilation, the "twin paradox", and $E=mc^2$. Calculus Vector transformations Tensors for GTR to understand why we need these two theories. For that see the problems with Galilean transformation & equivalence of inertial & gravitational mass. The most important thing to study SR is to accept geometry as the concept behind it. The math is not difficult; it's the way of thinking you have to adopt. Draw space time diagrams, something to transform to another frame of reference (Lorentz transforms are available). Keep in mind that the view in the other reference frame is just a different view of the same situation that nothing really has changed, even if it looks different on Euclidean paper.

Contents

1 Historical background
2 Fundamental concepts of special theory of relativity
3 Galilean transformations,
4 Lorentz transformations (for motion along one axis)
5 Length contraction
6 Time dilation
7 Simultaneity
8 Velocity addition formulae.3-dimensional
9 Lorentz transformations
10 Introduction to 4-vector formalism
11 Lorentz transformations in the 4-vector formalism
12 The Lorentz groups
13 The Poincare groups
14 Introduction to classical mechanics
15 Minkowski space-time & null cone
16 4-velocity & 4-momentum & 4-force
17 Application of special relativity to Doppler shift & Compton effect
18 Aberration of light
19 Particle scattering, Binding energy
20 Particle production & decay
21 Special relativity with small acceleration

Recommended Texts

1. Qadir, A. (1989). *An introduction to the special relativity theory* (1st ed.). Singapore: World Scientific.
2. Sardesai, P. L. (2008). *A primer of special relativity* (2nd ed.). Delhi: Offset.

Suggested Readings

1. Resnick, R. (1968). *Introduction to special relativity*. New York: Wiley.
2. D'Inverno, R. (1992). *Introducing Einstein's relativity* (1st ed.). Oxford: Oxford University Press.

MATH-6337 Numerical Solution of Partial Differential Equations 3(3+0)

This course addresses post graduate students of all fields who are interested in numerical methods for partial differential equations, with focus on a rigorous mathematical basis. Many modern & efficient approaches are presented, after fundamentals of numerical approximation are established. Of particular focus are a qualitative underst&ing of the considered partial differential equation, fundamentals of finite difference, finite volume, finite element, & spectral methods, & important concepts such as stability, convergence, & error analysis.Students who have successfully taken this module should be aware of the issues around the discretization of several different types of PDEs, have a knowledge of the finite element & finite difference methods that are used for discretizing, be able to discretise an elliptic partial differential equation using finite element & finite difference methods, carry out stability & error analysis for the discrete approximation to elliptic, parabolic & hyperbolic equations in certain domains. Students are able to solve following problems: advection equation, heat equation, wave equation, Airy equation, convection-diffusion problems, KdV equation, hyperbolic conservation laws, Poisson equation, Stokes problem, Navier-Stokes equations, interface problems.

Contents

1 Finite-Difference Formulae
2 Parabolic Equations
3 Finite difference methods
4 Convergence analysis
5 Stability analysis
6 Parabolic Equations
7 Alternative derivation of difference equations
8 Miscellaneous topics,
9 Hyperbolic equations
10 Characteristics,
11 Elliptic equations
12 Systematic iterative methods.

Recommended Texts

1. Morton, K. W., & Mayers, D. F. (2005). *Numerical solution of partial differential equations: An introduction* (2nd ed.). Cambridge: Cambridge University Press.
2. Bertoluzza, S., Falletta, S., Russo, G., & Chu, C. W. (1986). *Numerical solution of partial differential equations* (1st ed.). Basel: Birkhauser.

Suggested Readings

1. Ames, W. F. (1992). *Numerical methods for partial differential equations* (3rd ed.). New York: Academic Press.
2. Smith, G. D. (1986). *Numerical solution of partial differential equations: Finite difference Methods* (3rd ed.). Oxford: Oxford University Press.

MATH-6338 **Elasticity Theory** **3(3+0)**

This course is an introduction to the principal concepts and theory of elasticity. The course is intended to provide basic knowledge of Analysis of stress and strain; equilibrium; compatibility; elastic stress-strain relations; material symmetries. Elasticity theory is the mathematical framework which describes such deformation. By elastic, we mean that the material rebounds to its original shape after the forces on it are removed; a rubber eraser is a good example of an elastic material. The objectives of this course are to introduce to the students the analysis of linear elastic solids under mechanical & thermal loads, to introduce theoretical fundamentals & to improve the ability to use the principles of theory of elasticity in engineering problems. Students who successfully complete the course should be expert in using indicial notion, Cartesian tensor analysis, analysis of stress & deformation, basic filed equations of linear elastic solids & to formulate solution strategies of various boundary value problems.

Contents

1 Cartesian tensors
2 Analysis of stress
3 Analysis of strain
4 Generalized Hook's law
5 Crystalline structure
6 Point groups of crystals
7 Reduction in the number of elastic moduli due to crystal symmetry
8 Equations of equilibrium
9 Boundary conditions
10 Compatibility equations
11 Plane stress
12 Plane strain problems
13 Two dimensional problems in rectangular coordinates
14 Two dimensional problems in polar coordinates
15 Torsion of rods
16 Torsion of beams

Recommended Texts

1. Sokolinikoff, I. S. (1956). *Mathematical theory of elasticity* (2nd ed.). New York: McGraw Hill.
2. Dieulesaint, E., & Royer, D. (1974). *Elastic waves in solids* (1st ed.). New York: Wiley.

Suggested Readings

1. Funk, Y. C. (1965). *Foundations of solid mechanics (*1st ed.). New Jersey: Prentice – Hall.
2. Sadd, N. H. (2005). *Theory applications & numeric.* New York: Elsevier.
3. Boresi, A. P. (2000). *Elasticity in engineering mechanics.* New York*:* Wiley.

MATH-6339 **History of Mathematics** **2(2+0)**

This course is designed to provide the historical background to some of the mathematics familiar to students. This course is a survey of the historical development of mathematics. The emphasis will be on mathematical concepts, problem solving, and pedagogy from a historical perspective. In this course, we will explore some major themes in mathematics calculation, number, geometry, algebra, infinity, formalisms & their historical developments in various civilizations. We will see how the earlier civilizations influenced or failed to influence later ones & how the conceps evolved in these various civilizations. The aims of teaching & learning mathematics are to encourage & enable students to understand & be able to use the language, symbols & notation of mathematics, develop mathematical curiosity & use inductive & deductive reasoning when solving problems. Students will demonstrate their knowledge of basic historical facts; they will demonstrate understanding of the development of mathematics and mathematical thought.

Contents

1 History of Numerations
2 Egyptian
3 Babylonian
4 Hindu contributions
5 Arabic contributions
6 Algebra: Including the contributions of Al-Khwarzmi
7 Algebra: Including the contributions of Ibn Kura
8 History of Geometry
9 History of Euclud's elements
10 History of Analysis
11 The Calculus: Newton
12 The Calculus: Leibniz
13 The Calculus: Gauss
14 The contributions of Bernoulli brothers
15 The Twentieth Century Mathematics

Recommended Texts

1. Boyer, B., & Mersbach, U. V. (1989). *The history of mathematics* (2nd ed.). San Francisco: Jossey-Bass.
2. Berlinghoff, W. P., & Gouvea, F. Q. (2004). *Math through the ages: A gentle history for teachers & others* (Expanded ed.). London: Oxton House & MAA.

Suggested Readings

1. Burton, D. M. (2011). *The history of mathematics: An introduction* (7th ed.). New York: McGraw-Hill.
2. Katz, V. J. (2009). *A history of mathematics, an introduction* (3rd ed.). New York: Addison-Wesley.
3. Dunham, W. (1990). *Journey through genius: The great theorems of mathematics*. London: Penguin Pub.

MATH-6340 **Heat Transfer** **3(3+0)**

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, & exchange of thermal energy (heat) between physical systems. Heat transfer is classified into various mechanisms, such as thermal conduction, thermal convection, thermal radiation, & transfer of energy by phase changes. The objectives of heat transfer include the following: Insulation, wherein across a finite temperature difference between the system & its surrounding, the engineer seeks to reduce the heat transfer as much as possible. The learning outcomes of this course are: to explain the basics of heat transfer, to explain the importance of heat transfer, to define the concept of boiling & condensation, to define the concept of heat exchangers, to explain heat transfer by conduction, to explain the Fourier heat conduction law, to define thermal conductivity coefficient & diffusion coefficient, to explain heat transfer with convection, to explain Newton's law, to explain free transport phenomenon, to explain the forced convection, to explain heat transfer by radiation.

Contents

1 Steady-State Conduction-One Dimension
2 Steady-State Conduction-Multiples Dimensions
3 Unsteady-State Conduction,
4 Principles of Convection
5 Empirical & practical Relations
6 Forced –Convection Heat Transfer
7 Natural Convection Systems
8 Radiation Heat Transfer

Recommended Texts

1. Holman, J. P. (1996). *Heat transfer* (8th ed.). New York: McGraw Hill.
2. Kays, W. M., & Crawford, M. E. (1993). *Convective heat & mass transfer* (*3*rd ed.). New York: McGraw Hill.

Suggested Readings

1. Incropera, F. P., & Dewitt, D. P. (1985). *Fundamentals of heat & mass transfer* (2nd ed.). New York: Wiley.
2. Cenegel, Y., & Ghajar, A. J. (2015). *Heat & mass transfer: Fundamentals & applications* (5th ed.). New York: Mc-Graw Hill.
3. Lienhar IV, J. H., & Lienhar V, J. H. (2019). *A heat transfer textbook* (5th ed.). New York: Dover Publications.
4. Incropera, F. P. (2006). *Fundamentals of heat & mass transfer* (6th ed.). New York: John Wiley & Sons.

MATH-6341 **Bio-Mathematics** **3(3+0)**

Mathematical & theoretical biology is a branch of biology which employs theoretical analysis, mathematical models & abstractions of the living organisms to investigate the principles that govern the structure, development & behavior of the systems, as opposed to experimental biology which deals with the conduction of experiments to prove & validate the scientific theories. The objective of this course is to meet the current & future needs for the interaction between mathematics & biological sciences. Mathematical modeling is being applied in every major discipline in the biomedical sciences. A very different applications, & surprisingly successful, is in psychology, modeling of various human interactions, blood flow & functioning of different organs in human body. Mathematics may be divided into the broad categories of analysis (calculus), algebra, geometry & logic. This subject fit largely into the calculus category & follows on from material you will have learned in first year & from other related courses you may have taken, although algebra & areas will also be involved. This course is very useful for those majoring in Applied Mathematics, those planning to teach, or those students of Mathematics who are interested in the application of mathematical techniques to real-world problem solving.

Contents

1 An introduction to the use of continuous differential equations in the biological sciences
2 An introduction to the use of discrete differential equations in the biological sciences
3 Single species
4 Interacting population dynamics
5 Modeling infectious & dynamic diseases
6 Modeling infectious diseases
7 Modeling dynamic diseases
8 Regulation of cell function,
9 Molecular interactions
10 Neural & biological oscillators
11 Introduction to biological pattern formation
12 Mathematical tools such as phase portraits
13 Bifurcation diagrams
14 Perturbation theory
15 Parameter estimation techniques
16 Interpretation of biological models.

Recommended Texts

1. Murray, J. D. (2001). *Mathematical biology.* New York: Springer-Verlag.
2. Britton, N. F. (2003). *Essential mathematical biology*. New York: Springer- Verlag

Suggested Readings

1. Keener, J., & Sneyd, J. (1998). *Mathematical physiology*. New York: Springer.
2. Edelstein-Keshet, L. (1988). *Mathematical models in biology*. New York: R&om House.

MATH-6342 **Theory of Automata** **3(3+0)**

Automata theory is the study of abstract machines & automata, as well as the computational problems that can be solved using them. It is a theory in theoretical computer science. The word automata (the plural of automaton) comes from the Greek word αὐτόματα, which means "self-making". The major objective of automata theory is to develop methods by which computer scientists can describe & analyze the dynamic behavior of discrete systems, in which signals are sampled periodically. ... Inputs: assumed to be sequences of symbols selected from a finite set I of input signals. The aim is to introduce to the students to the foundations of computability theory. Other objectives include the application of mathematical techniques & logical reasoning to important problems, & to develop a strong background in reasoning about finite automata & formal languages. At the end of the course the students should be able to: define the notion of countable & uncountable set, define the various categories of languages & grammars, define various categories of automata, define the notion of computability & decidability, & reduce a problem to another(when possible) to develop proofs of decidability/undecidibility. The course introduces some fundamental concepts in automata theory & formal languages including grammar, finite automaton, regular expression, formal language, pushdown automaton, & Turing machine. Not only do they form basic models of computation, they are also the foundation of many branches of computer science, e.g. compilers, software engineering, concurrent systems, etc.

Contents

1 Regular expressions
2 Regular Languages
3 Finite Automata
4 Context-free Grammars
5 Context-free languages
6 Push down automata
7 Decision Problems
8 Parsing
9 Turing Machines

Recommended Texts

1. Martin, J. C. (2010). *Introduction to languages & theory of computation* (4th ed.). New York: Mc Graw Hill.

Suggested Readings

1. Cohen, D. I. A. (1996). *Introduction to computer theory* (2nd ed.). New York: Wiley.
2. Linz, P. (2017). *Introduction to formal languages & automata* (6th ed.). New York: Jones & Barlett.
3. Michael S. (2013). *Introduction to the theory of computation* (3rd ed.). New York: Cengage Learning.

MATH-6343 Measure Theory 3(3+0)

The objectives of the course are to introduce the concepts of measure & integral with respect to a measure, to show their basic properties, to provide a basis for further studies in analysis, probability, & dynamical Systems, to construct Lebesgue's measure & learn the theory of Lebesgue integrals on real line & in n-dimensional Euclidean space. The goal of the course is to develop the understanding of basic concepts of measure and integration theory. As measure theory is a part of the basic curriculum since it is crucial for understanding the theoretical basis of probablity and statistics, so it is intended to develop understanding of the theory based on examples of application. After the course the students will know & understand the basic concepts of measure theory & the theory of Lebsgue integration. The students will understand the main proof techniques in the field & will also be able to apply the theory abstractly & concretely. The students will be able to write the elementary proofs himself, as well as more advanced proofs under guidance. The students will be able to use measure theory & integration in Riemann integration & calculus.

Contents

1 Introduction to Lebesgue measure
2 Outer measure
3 Properties of outer measure
4 Further properties of outer measure
5 Measurable sets
6 Properties of measurable sets
7 Non measurable sets
8 Measurable functions
9 Properties of measurable functions
10 Convergence of sequences of measurable functions
11 Lebesuge integration, introduction
12 Lebesgue integrals of simple
13 Bounded functions
14 Lebesgue integrals of non negative functions
15 Lebesgue integration of general functions
16 General convergence theorems
17 convergence in measure

Recommended Texts

1. Roydon, H. L., & Fitzpatrick, P. M. (2017). *Real analysis* (4th ed.). New York: Collier Macmillan Co.
2. Barra, G. D. (1981). *Measure theory & integration* (1st ed.). Ellis: Harwood Ltd.

Suggested Readings

1. Rudin, W. (1987). *Real & complex analysis,* (3rd ed.). New York: McGraw Hill Book Company.
2. Bartle, R.G. (1995). *The elements of integration & Lebesgue measure* (1st ed.). Wiley-Interscience.
3. Halmos, P. R. (1975). *Measure theory* (1st ed.). New York: Springer.

MATH-6344 **Special Functions** **3(3+0)**

Special functions are particular mathematical functions that have more or less established names & notations due to their importance in mathematical analysis, functional analysis, geometry, physics, or other applications. The term is defined by consensus, & thus lacks a general formal definition, but the List of mathematical functions contains functions that are commonly accepted as special. The main aim of this course is the study of basic special functions & proves the properties & relations related to these functions. Furthermore, the simple sets of polynomials are discussed.

Contents

1 The Weierstrass gamma function
2 Euler integral representation of gamma function
3 Relations satisfied by gamma function
4 Euler's constant
5 The order symbols o & O
6 Properties of gamma function
7 Beta function, integral representation of beta function
8 Relation between gamma & beta functions
9 Properties of beta function, Legendre's duplication formula
10 Gauss' multiplication theorem
11 Hypergeometric series, the functions F(a,b;c;z) & F(a,b;c;I), integral representation of hypergeometric function,
12 The hypergeometric differential equation, The contiguous relations, Simple transformations,
13 A theorem due to Kummer,
14 Confluent hypergeometric series, Integral representation of confluent hypergeometric function, the confluent hypergeometric,
15 Differential equation, Kummer's first formula
16 Simple sets of polynomials, Orthogonality,
17 The three term recurrence relation, The Christofell-Darboux formula,
18 Normalization, Bessel's inequality
19 Generating functions
20 Differential equations
21 Recurrence relations.

Recommended Texts

1. Richard, B. (2016). *Special functions & orthogonal polynomials*. Cambridge: Cambridge University Press.
2. Rainville, E. D. (1971). *Special functions* (3rd ed.). New York: The Macmillan Company

Suggested Readings

1. Whittaker, E. T., & Watson, G. N. (1978). *A course in modern analysis*, (2nd ed.). Cambridge : Cambridge University Press.
2. Lebedev, N. N. (1972). *Special functions & their applications* (2nd ed.). New York: Prentice Hall.

MATH-6345 **Theory of Splines-I** **3(3+0)**

This is the first part of the two-course series of Theory of Splines. This course is designed to teach students about basics of scientific computing for solving problems which are generated by data using interpolation & approximation techniques & learn how to match numerical method to mathematical properties. This course gives the students the knowledge of problem classes, basic mathematical & numerical concepts & software for solution of engineering & scientific problems formulated as using data sets. After successful completion, students should be able to design, implement & use interpolations for computer solution of scientific problems involving problems generated by set of data. The material covered provides the studnets with the necessary tools for understanding the many applications of splines in such diverse areas as approximation theory, computer-aided geometric design, curve and surface design and fitting, image processing, numerical solution of differential equations, and increasingly in business and the biosciences.

Contents

1 Basic concepts of Euclidean geometry
2 Scalar & vector functions
3 Barycentric coordinates
4 Convex hull, Matrices of affine maps, Translation, rotation, scaling
5 Reflection & shear, Curve fitting, least squares line fitting
6 Least squares power fit
7 Data linearization method for exponential functions
8 Nonlinear least-squares method for exponential functions
9 Transformations for data linearization
10 linear least squares, Polynomial fitting,
11 Basic concepts of interpolation, Lagrange's method,
12 Rrror terms & error bounds of Lagrange's method
13 Divided differences method,
14 Newton polynomials, error terms & error bounds of Newton polynomials
15 Central difference interpolation formulae
16 Gauss's forward interpolation formula
17 Gauss's backward interpolation formula, Hermite's methods

Recommended Texts

1. David, S. (2006). *Curves & surfaces for computer graphics*. New York: Springer Science + Business Media Inc.
2. John, H. M., & Kurtis, D. F. (1999). *Numerical methods using MATLAB*. New Jersey: Prentice Hall.

Suggested Readings

1. Rao, S. S. (1992). *Optimization theory & applications* (2nd ed.). New York: Wiley Eastern Ltd.
2. Sudaran R. K. (1996). *A first course in optimization theory* (3rd ed.). Cambridge: Cambridge University Press.
3. Chang E. K. P., & Zak, S. I. I. (2004). *An introduction to optimization* (3rd ed.). New York: Wiley.

MATH-6346 **Theory of Splines-II** **3(3+0)**

This is the second part of the two-course series of Theory of Splines. The goal of the course is to provide the students with a strong background on numerical approximation strategies & a basic knowledge on the theory of splines that supports numerical algorithms. Interactive graphics techniques for defining & manipulating geometrical shapes used in computer animation, car body design, aircraft design, & architectural design. In this course follow a modular approach & contribute different components to the development of an interactive curve & surface modeling system. Curve Modeling Techniques: Students will implement various curve interpolation & approximation techniques that allow the interactive specification of three-dimensional curves (e.g. Bezier, B-spline, rational curves). Surface modeling techniques: Students will implement various surface interpolation & approximation techniques that allow the interactive specification of three-dimensional surfaces (e.g. Bezier, B-spline, rational surfaces). Simple, 3D Modeling System: Students will integrate the curve & surface modules into a system that allows the user to interactively design & store simple, 3D geometries.

Contents

1 Parametric curves (scalar & vector case), Algebraic form
2 Hermite form, control point form, Bernstein Bezier form
3 Matrix forms of parametric curves
4 Algorithms to compute B.B. form, Convex hull property
5 Affine invariance property, Variation diminishing property
6 Rational quadratic form, Rational cubic form
7 Tensor product surface, B.B. cubic patch
8 Quadratic by cubic B.B. patch, B.B. quartic patch, Splines, Cubic splines
9 End conditions of cubic splines, Clamped conditions
10 Natural conditions, second derivative conditions
11 Periodic conditions, Not a knot conditions
12 General splines, Natural splines, Periodic splines
13 Truncated power function, Representation of spline in terms of truncated power functions
14 Odd degree interpolating splines

Pre-requisite: Theory of Splines-I

Recommended Texts

1. Farin, G. (2002). C*urves & surfaces for computer aided geometric design, a practical guide* (5th ed.). New York: Academic Press.
2. Faux, I. D., & Pratt, M. J. (1979). *Computational geometry for design & manufacture* (1st ed.). New York: Halsted Press.

Suggested Readings

1. Bartle, H. R., & Beatly, C. J. (2006). *An Introduction to spline for use in computer graphics & geometric modeling* (4th ed.). Massachusetts: Morgan Kaufmann.
2. Boor, C. D. (2001). *A practical guide to splines* (Revised ed.). New York: Springer Verlag.

MATH-6347 **Methods of Optimization-I** **3(3+0)**

Optimization is a widely used technique in operational research that has been employed in a range of applications. The aim is to maximize or minimize a function (e.g. maximizing profit or minimizing environmental impact) subject to a set of constraints. At the start of the course, the course delivery, the prerequisites of the course will be discussed. The objective of this course is to make students acquire a systematic understanding of optimization techniques. The course will start with linear optimization (being the simplest of all optimization techniques) and will discuss in detail the problem formulation and the solution approaches. Then we will cover a class of nonlinear optimization problems where the optimal solution is also globally optimal, i.e. convex nonlinear optimization and its variants. On successful completion of the course the students will be able to model engineering maxima/minima problems as optimization problems. The students will be able to use computers to implement optimization algorithms. The students will learn efficient computation procedures to solve optimization problems.

Contents

1 Introduction to optimization
2 Review of related mathematical concepts
3 Unconstrained optimization
4 Conditions for local minimizers
5 One dimensional search methods
6 Gradient methods
7 Newton's method (analysis & modifications)
8 Conjugate direction methods
9 Quasi Newton method
10 Application to neural network
11 Single Neuron Training
12 Linear integer programming
13 Genetic algorithms
14 Real number genetic algorithm

Recommended Texts

1. Chong, E. K. P., & Stanislaw, H. Z. (2012). *An introduction to optimization* (4th ed.). New York: Wiley Series in Discrete Mathematics & Optimization.
2. Singiresu, S. R. (1992). *Optimization theory & applications* (2nd ed.). New York: Wiley Eastern Ltd.

Suggested Readings

1. Sundaram, R. K. (1996). *A first course in optimization theory,* (3rd ed.). Cambridge: Cambridge University Press.
2. Bertsimas, D., Tsitsiklis, J. N., & Tsiitsiklis, J. (1997). *Introduction to lineae optimization* (2nd ed.). Belmont: Athena Scientific

MATH-6348 **Methods of Optimization-II** **3(3+0)**

This is continuation of Methods of Optimization I. Optimization is a widely used technique in operational research that has been employed in a range of applications. The aim is to maximize or minimize a function (e.g. maximizing profit or minimizing environmental impact) subject to a set of constraints. At the start of the course, the course delivery, the prerequisites of the course will be discussed. Students will learn the foundations of linear programming, properties of optimal solutions and various solution methods for optimizing problems involving a linear objective function and linear constraints. Students will be exposed to geometric, algebraic and computational aspects of linear optimization and its extensions. On successful completion of the course the students will be able to model engineering maxima/minima problems as optimization problems. The students will be able to use computers to implement optimization algorithms. The students will learn efficient computation procedures to solve optimization problems.

Contents

1 Non-linear constrained optimization
2 Problems with equality constraints
3 Problem Formulation
4 Tangent spaces
5 Normal spaces
6 Lagrange condition
7 Second-order conditions
8 Problems with inequality constraints
9 Karush-Kuhn-Tucker Condition
10 Second-order conditions
11 Convex optimization problems
12 Convex functions
13 Algorithms for constrained optimization
14 Lagrangian algorithms

Pre-requisite: Methods of Optimization-I

Recommended Texts

1. Chong, E. K. P., & Stanislaw, H. Z. (2012). *An introduction to optimization* (4th ed.). New York: Wiley Series in Discrete Mathematics & Optimization.
2. Singiresu, S. R. (1992). *Optimization theory & applications* (2nd ed.). New York: Wiley Eastern Ltd.

Suggested Readings

1. Sundaram, R. K. (1996). *A first course in optimization theory,* (3rd ed.). Cambridge: Cambridge University Press.
2. Bertsimas, D., Tsitsiklis, J. N., & Tsiitsiklis, J. (1997). *Introduction to lineae optimization* (2nd ed.). Belmont: Athena Scientific

MATH-6349 **Control Theory** **3(3+0)**

This course is an introduction to analysis and design of feedback control systems, including classical control theory in the time and frequency domain. Modeling of physical, biological and information systems using linear and nonlinear differential equations. Stability and performance of interconnected systems, including use of block diagrams, Bode plots, Nyquist criterion, and Lyapunov functions. Robustness and uncertainty management in feedback systems through stochastic and deterministic methods. Introductory random processes, Kalman filtering, and norms of signals and systems. In control system engineering is a subfield of mathematics that deals with the control of continuously operating dynamical system in engineered processes & machines. The objective is to develop a control model for controlling such systems using a control action in an optimum manner without delay or overshoot & ensuring control stability.

Contents

1 System dynamics & differential equations, some system equations
2 System control
3 Mathematical methods & differential equations, The classical & modern control theory
4 Transfer functions & block diagram, Review of Laplace Transforms
5 Applications to differential equations, Transfer functions & Block diagrams
6 State space formations, State space forms, using transfer functions to define state variables, direct solution of the state equation
7 Solutions of the state equation by Laplace transforms, the transformation from companion to the diagonal state form
8 The transform function from the state equation, Transient & steady state response analysis
9 Response of first order system, Response of second order system, Response of higher order systems
10 Steady state error, Feedback control, The concept of stability
11 Routh stability criterion, Introduction to Liapunor's method, Quadratic form
12 Determination of liapunov's function,
13 The Nyquist stability criterion
14 The frequency response
15 An introduction to conformal mapping
16 Applications of conformal mappings to the frequency response
17 Controllability, Observability, Decomposition of system state
18 A transformation into the companion form
19 State feedback of SISO system, Multivariable system observations

Recommended Texts

1. Burghes, D., & Graham, A. (1980). *Introduction to control theory including optimal control*. New York: Ellis Horwood Ltd.

Suggested Readings

1. Barnett, S., & Camron, R. G. (1985). *Introduction to mathematical control theory* (2nd ed.). Oxford: Oxford V. P.

MATH-6350 **Applied Matrix Theory** **3(3+0)**

Matrix theory is a branch of mathematics which is focused on study of matrices. Initially, it was a sub-branch of linear algebra, but soon it grew to cover subjects related to graph theory, algebra, combinatorics & statistics as well. The aim is to introduce the key mathematical ideas in matrix theory, which are used in modern methods of data analysis, scientific computing, optimization, & merely all quantitative fields of science & engineering. While the choice of topics is motivated by their use in various disciplines, the course will emphasize the theoretical & conceptual underpinnings of this subject, just as in other (applied) mathematics course. The focus of this course is to study the basics of matrices & their applications. Moreover, it concerns with the variational principles, Weyl's inequalities, Gershgorin's theorem & perturbations of the spectrum. The objective is to introduce the key mathematical ideas in matrix theory, which are used in modern methods of data analysis, scientific computing, optimization, & merely all quantitative fields of science & engineering. While the choice of topics is motivated by their use in various disciplines, the course will emphasize the theoretical & conceptual underpinnings of this subject, just as in other (applied) mathematics course.

Contents

1 Eigen values
2 Eigen vectors
3 The Jordan canonical forms
4 Bilinear & quadratic forms
5 Matrix analysis of differential equations
6 Variational principles
7 Perturbation theory
8 The Courant minimax theorem
9 Weyl's inequalities
10 Gershgorin's theorem
11 Perturbations of the spectrum
12 Vector norms & related matrix norms
13 The condition number of a matrix

Recommended Texts

1. Strang, G. (2005). *Linear algebra & its applications*. Cambridge: Academic Press.
2. William, G. (2009). *Linear algebra with applications* (7th ed.). Boston: Allyn & Bacon, Inc.

Suggested Readings

1. Stewart, G. W. (1973). *Introduction to matrix computations*. New York: Academic Press.
2. Franklin, J. N. (2000). *Matrix theory* (1st ed.). New York: Dover Publications.
3. Laub, A. J. (2005). *Matrix analysis for scientsts and engineers*. United States: SIAM.