CBCS STRUCTURE (w.e.f. 2022) of North Bengal University

Department: Mathematics	Programme Name: PG in Mathematics

Semester I				
Course Type	Choice	Course Title	Course Credit	Total Credit
Core	None	1. Groups and Rings 2. Naive Set Theory and Elements of Topology 3. Analysis of Several Variables 4. Real Analysis 5. Complex Analysis 6. Ordinary Differential Equations and Special Functions	2 2 2 2 2 2	16
DSE	Choose any one	1. Programming Language 2. Mathematical skills for problem solving	2	
AEC	Choose any one from Basket 1		2	

Semester-II				
Course Type	Choice	Course Title	Course Credit	Total Credit
Core	None	1. Modules and Linear Algebra 2. Point-Set Topology 3. Functional Analysis 4. Classical Mechanics and Calculus of Variation 5. Integral Equations and Integral Transforms 6. Partial Differential Equations	2 2 2 2 2 2	16
DSE	Choose any one	1. Mathematical Type-setting, Report writing, and Seminar Presentation 2. Social Outreach Programme	2	
SEC	Choose any one from Basket 2		2	

Semester III					
Course Type	Choice		Course Title	Course Credit	Total Credit
Core	None		1. Differential Geometry and Its Applications	2	16
			2. Field Extension and Galois Theory	2	
DSE	Choose any three either from A or from B	A	1. Continuum Mechanics	2	
			2. Advanced Partial Differential Equations	2	
			3. Computational Partial Differential Equations	2	
			4. Non-linear Partial Differential Equations	2	
			5. Dynamical Systems	2	
			6. Fluid Mechanics	2	
			7. Quantum Mechanics	2	
			8. Statistical Learning	2	
		B	1. Measurability and Integration in Abstract Spaces	2	
			2. Algebraic Topology	2	
			3. Elementary Number Theory	2	
			4. Advanced Complex Analysis-I	2	
			5. Advanced Functional Analysis	2	
			6. Theory of Approximation	2	
			7. Fuzzy Mathematics	2	
			8. Algebraic Geometry	2	
			9. Category Theory	2	
			10. General Theory of Integration	2	
AEC	Choose 1 from Basket 3			2	
GE	Choose any one		1. Mathematical Spaces and Curves	4	
			2. Statistical foundation for Data Science	4	
			3. Mathematical Modelling and Simulations in MATLAB and MATHEMATICA	4	

Semester IV					
Course Type	Choice		Course Title	Course Credit	Total Credit
Core	None		1. Dissertation	2	16
			2. Graph Theory	2	
			3. Numerical Analysis	2	
			4. Numerical Problem solving by Computer Programming (Practical)	2	
DSE	Choose any one either from A or from B	A	1. Boundary Integral Equations	2	
			2. Mathematical Ecology	2	
			3. Bio-fluid Mechanics	2	
			4. General Theory of Relativity and Cosmology	2	
			5. Lie Theory of Ordinary and Partial Differential Equations	2	
			6. Nonlinear Optimization	2	
			7. Computational Statistics	2	
		B	1. Signed Measure and Product Measure	2	
			2. Topological Groups	2	
			3. Analytic Number Theory	2	
			4. Advanced Complex Analysis-II	2	
			5. C*-Algebra	2	
			6. Advanced Algebra	2	
			7. Modular Forms	2	
			8. p-adic Analysis	2	
			9. Complex Differential Equations	2	
SEC	Choose any one from Basket 4			2	
GE	Choose any one		1. Discrete Mathematics, Data Structure and Algorithms	4	
			2. Mathematical Physics	4	
			3. Fundamentals of Biomathematics	4	
			4. Introduction to Mathematical Finance	4	
			5. Mathematical Cryptography	4	

Department Name:	Mathematics
Program Name:	PG in Mathematics
Program Code:	

Semester: **Semester I ☑** Semester II ☐ Semester III ☐ Semester IV ☐

Course Name:	Groups and Rings
Course Code:	MATH-CC-101
Course Credit:	2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-101

Course Name: Groups and Rings

Brief Course Description:

Groups: Direct product of groups, Group action, Simple groups, Solvable groups, Free groups. **Rings:** Maximal ideals, Prime ideals, Unique Factorization Domain, Polynomial rings, Irreducibility criterion, Noetherian Rings. Artinian Rings.

Prerequisite(s) and/or Note(s):

Functions, Groups, Rings, Fields, Ideals and Integral domains at under graduate level.

Course Objectives:

Knowledge acquired:

(1) Concept of group action
(2) Class equation and its applications
(3) Sylow's Theorems and their applications
(4) Ideal of a ring, Polynomial rings
(5) EDs, PIDs &UFD's and relations among them

Skills gained:

(1) Solving problems using the powerful concept of group action
(2) Finding the number of subgroups, normal subgroups of a finite group
(3) Ability to understand a large class of commutative rings by regarding them as quotients of polynomial rings by suitable ideals

Competency developed:

(1) Applying the concept of a group action to real life problem such as Counting
(2) Facility in handling problems involving polynomial equations
(3) Facility in working with situations involving commutative rings
(4) Ability to understand the various PID's whose common example is the ring of integers $\mathbb{Z}$

Course Syllabus:

- Direct product of groups, Finite Abelian groups, Group action, Class equation, Cauchy's theorem, Sylow's theorems, Generalized Cayley's theorem.
- Simple groups, Solvable groups, Nilpotent groups, Simplicity of alternating groups, Normal and subnormal series, Composition series, Jordan–Holder theorem, Semi direct product, Free groups, Free Abelian groups.
- Maximal ideals, Prime ideals, ED, PID, UFD.
- Polynomial rings, Division algorithm in polynomial rings, Irreducibility of Polynomials, Eisenstein's criterion of irreducibility, Noetherian Rings. Artinian Rings, Hilbert Basis Theorem, Primary ideals, Primary decomposition theorem.

Suggested Readings:

Abstract Algebra,
D. S. Dummit, R. M. Foote,
John Wiley and Sons.

Algebra
S. Lang,
Springer
Topics in Abstract Algebra,
M. K. Sen, S. Ghosh, P. Mukhopadhyay, S. K. Maity,

Universities Press.

Contemporary Abstract Algebra,
J. R. Gallian,
Narosa Publishing House.

A First Course in Abstract Algebra,
J. B. Fraleigh,
Narosa Publishing House.

Algebra,
M. Artin,
Prentice Hall.

Topics in Abstract Algebra,
I. N. Herstein,
Wiley Eastern Limited.

Fundamentals of Abstract Algebra,
D. S. Malik, J. N. Mordeson, M. K. Sen,
McGraw-Hill, International Edition, 1997.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I** ☑ Semester II ☐ Semester III ☐ Semester IV ☐

Course Name: Naive Set Theory and Elements of Topology

Course Code: MATH-CC-102

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? **YES**☑ NO ☐

Is the course focused on imparting life skill? **YES**☑ NO ☐

Is the course based on Activity ? **YES**☑ NO ☐

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☑

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

The theory of nets and filters have been incorporated as sophisticated mathematical tools to prove theorems/results in some easier way. Not only that those theories also used to characterize many topological properties which are not achieved by the theory of sequences.

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-102

Course Name: Naive Set Theory and Elements of Topology

Brief Course Description:

'Naive Set Theory and Elements of Topology' deals with the topics related to Naive set theory and elements of topology. In particular, the course will cover set theory with special emphasis on ordinal and cardinal numbers, topological spaces, continuous maps, countability and separation axioms, connected spaces, compact spaces, nets, filters and related topics.

Prerequisite(s) and/or Note(s):

(1) Graduate level mathematics.
(2) Note(s): Syllabus changes yearly and may be modified during the term itself, depending on the circumstances. However, students will be evaluated only on the basis of topics covered in the course.

Course Objectives:

Knowledge acquired:

(1) Set as a domain of thought in Mathematical Sciences
(2) Conversion of Necked Set into Mathematical structure
(3) Cardinality of Sets (that can distinguish even infinite sets having huge difference in some sense) and Ordinal Numbers
(4) A fast journey from Metric space to Topological space
(5) How roots of analysis are spread within Topological spaces
(6) Equality in Topological sense and its relevance
(7) Properties of Topological Spaces (Separation Axioms, Compactness, Connectedness)
(8) Inadequacy of sequence and its recovery by Nets and Filters

Skills gained:

(1) Analysis on Abstract Spaces to some extent
(2) Analysis without concepts of length or distance

Competency developed:

Ability of real/complete understanding of analysis and feelings of identity in differences

Course Syllabus:

- Axiom of choice and existence of choice function. Partially ordered set, linearly ordered set, well ordered set and product of the same kinds, Zorn's lemma, well ordering principle with special emphasis on Ordinal and Cardinal numbers.
- Topological spaces, open and closed sets, basis and sub-basis, closure, interior and boundary of a set. Subspace topology. Continuous maps: properties and constructions; Pasting Lemma. Open and closed maps, Homeomorphisms. Product topology, Quotient topology and examples of Topological Manifolds.
- Countability and separation axioms: Urysohn's lemma, Tietze extension theorem and applications. Urysohn embedding lemma and metrization theorem for second countable spaces.
- Connected, path-connected and locally connected spaces. Lindelof and compact spaces. Net, filters.

Suggested Readings:

Topology: a first course,
J. R. Munkres
Prentice Hall.

Introduction to Topology and Modern Analysis,
G. F. Simmons
TataMcGraw-Hill.

Basic Topology,
M. A. Armstrong
Springer.

General Topology,
J. L. Kelley
Springer-Verlag.

Topology,
J. Dugundji
UBS.

General Topology,
S. Willard
Dover.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I ☑** Semester II ☐ Semester III ☐ Semester IV ☐

Course Name: Analysis of Several Variables

Course Code: MATH-CC-103

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-103

Course Name: Analysis of Several Variables

Brief Course Description:

Topology of $\mathbb{R}^n$, compactness and connectedness, Derivative, Continuous differential functions, Chain rule, Inverse and Implicit function theorem, Existence of integral over a Rectangle and bounded set, Rectifiable sets, Improper integral, Change of variables, Diffeomorphism on $\mathbb{R}^n$, Manifolds, Integration a scalar function over a manifold, Divergence, Gradient and Curl, Green's theorem, Gauss Divergence theorem and Stoke's theorem.

Prerequisite(s) and/or Note(s):

(1) Graduate level mathematics.
(2) Note(s): Syllabus changes yearly and may be modified during the term itself, depending on the circumstances. However, students will be evaluated only on the basis of topics covered in the course.

Course Objectives:

Knowledge acquired:

(1) Differentiability of maps from $\mathbb{R}^m$ to $\mathbb{R}^n$ and the derivative as a linear operator
(2) Jacobian matrix
(3) Chain rule. Notions of partial derivatives
(4) Inverse and implicit function theorems
(5) Existence of the Riemann integral for sufficiently well-behaved functions on rectangles, i.e., product of intervals
(6) Fubini's theorem
(7) Partitions of unity
(8) Change of variables and the Jacobian formula
(9) Picard's Theorem, Green's theorem, Gauss (Divergence) theorem and Stoke's theorem

Skills gained:

(1) Generalization of concept of differentiability
(2) Generalization of concept of integrability
(3) Generalization of theorems

Competency developed:

(1) Ability to solve higher dimensional derivatives
(2) Ability to solve higher dimensional integration
(3) Apply inverse and implicit function theorems

Course Syllabus:

- Topology of $\mathbb{R}^n$, $GLn(\mathbb{R})$etc. Differentiability of maps from $\mathbb{R}^m$ to $\mathbb{R}^n$ and the derivative as a linear map.
- Determinant as mapping; its continuity and differentiability, is a real square matrix.
- Higher derivatives, Chain Rule, mean value theorem for differentiable functions, Taylor expansions in several variables, Local maxima and minima, Lagrange multiplier, Sard's theorem.
- Multiple integrals, Existence of the Riemann integral for sufficiently well-behaved functions on rectangles, i.e., product of intervals. Multiple integrals expressed as iterated simple integrals. Brief treatment of multiple integrals on more general domains. Change of

variables and the Jacobian formula, illustration with plenty of examples. Inverse and implicit function theorems. Picard's Theorem.

- Curves in $\mathbb{R}^2$ and $\mathbb{R}^3$. Line integrals, Surfaces in $\mathbb{R}^3$, Surface integrals, Integration of forms, Divergence, Gradient and Curl operations, Green's theorem, Gauss Divergence theorem and Stoke's theorem.

Suggested Readings:

Calculus on Manifolds,
M. Spivak,
Benjamin (1965).

Principles of mathematical Analysis,
W. Rudin,
Mc Graw-Hill.

Mathematical Analysis,
T. M. Apostol,
Addison-Wesley (2007).

Analysis on Manifolds,
J. Munkres,
CRC Press (2018).

Calculus (Vol 2),
T. M. Apostol,
John Wiley.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I ☑** Semester II ☐ Semester III ☐ Semester IV ☐

Course Name: Real Analysis

Course Code: MATH-CC-104

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-104

Course Name: Real Analysis

Brief Course Description:

Extended real numbers, Lebesgue outer measure on R, a non-Lebesgue measurable set, regularity of Lebesgue outer measure, Borel measurability on R, measurable functions, sequence of measurable functions, Cantor ternary set and Cantor-Lebesgue function.
Abstract measure spaces, σ-algebra of sets, Borel σ-algebra, measure on σ-algebra, monotone convergence theorems.

Prerequisite(s) and/or Note(s):

(1) Real analysis, Metric space.
(2) Note(s): Syllabus changes yearly and may be modified during the term itself, depending on the circumstances. However, students will be evaluated only on the basis of topics covered in the course.

Course Objectives:

Knowledge acquired:

(1) Concept of extended real numbers, Lebesgue and Borel measures on real line
(2) Measurability of real sets
(3) Measurability of extended real valued functions
(4) Foundation of extension to abstract spaces

Skill gained:

(1) Solving problems relating to determinations of measures of finite, infinite sets
(2) Ability of constructing different Borel sets
(3) Ability of constructing measurable, non-measurable sets and functions

Competency developed:

(1) Applying results to the later topics, namely in abstract spaces
(2) Applying the notions for the study of subtle concepts like Cantor sets

Course Syllabus:

- Extended real numbers, algebraic operations and convergence in extended real number system, Lebesgue outer measure on R, elementary properties of Lebesgue measure space including σ-finiteness, translation invariance, positive homogeneity, existence of non-Lebesgue measurable sets, regularity of Lebesgue outer measure,
- Borel measurability on R, measurable functions, operations with measurable functions, sequence of measurable functions, Cantor ternary set and Cantor-Lebesgue function.
- Abstract measure spaces, σ-algebra of sets, limits of sequences of sets, Borel σ-algebra, measure on σ-algebra, measurable spaces and measure spaces, monotone convergence theorems for sequences of measurable sets.

Suggested Readings:

Fundamentals of Real Analysis,
S K. Berberian,
Springer.

Measure Theory and Integration,
G. De Barra,
New Age International Publ.

Real Analysis,
H. L. Royden,
Prentice-Hall of India Pvt. Limited, (1988).

Principles of Mathematical Analysis,
W. Rudin,
McGraw-Hill, (2013).

Lectures on Real Analysis,
J. Yeh,
World Sci.

The Elements of Integration,
R. G. Bartle,
John Wiley & Sons, Inc. New York, (1966).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I ☑** Semester II ☐ Semester III ☐ Semester IV☐

Course Name: Complex Analysis

Course Code: MATH-CC-105

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-105

Course Name: Complex Analysis

Brief Course Description:

This course deals with integration of a complex valued functions, Cauchy's Theorem Cauchy's Integral formula, Zeros of an analytic function, Singularities and their classification, Cauchy's Residue Theorem, Maximum modulus theorems, Conformal mappings, Möbius transformation, Analytic continuation and Monodromy theorem.

Prerequisite(s) and/or Note(s):

Students are assumed to have the knowledge of graduate level algebra, analysis and calculus.

Course Objectives:

Knowledge acquired:

(1) Analytic functions, Power series as analytic function, Cauchy-Riemann differential equations
(2) Concept of Complex Integration, Cauchy's theorem, Cauchy's integral formula and their applications, Morera's theorem, Liouville's theorem, Zeros of analytic function and related properties
(3) Singular point of analytic functions and their classification, Residue theorem, Maximum modulus theorem and its applications
(4) Concept of Analytic Continuation and Monodromy theorem

Skills gained:

(1) Differentiation of functions on C, deciding if a function on C is analytic. Development of analytic functions into power series
(2) Evaluation of Complex Line integrals. Range of a bounded entire function
(3) Deciding if a region contains zeroes of Analytic functions.
(4) Deciding if the domain of an analytic function may be extended
(5) Finding location of maximum and minimum points of an analytic function in a region

Competency developed:

(1) Understanding of topological and geometric properties of the complex plane
(2) Differentiation and integration of functions on C
(3) Evaluation of Complex Line integrals. Range of a bounded entire function
(4) Evaluation of Real Definite Integrals. Ability of finding the region containing the zeros of analytic functions
(5) Ability to extend the domain of analytic function

<u>Course Syllabus</u>:

- Complex integration, Winding number or Index of a closed curve, Homotopy version of Cauchy's Theorem, Morera's theorem, primitives of analytic functions, Zeros of an analytic function, Open mapping theorem, Inverse function theorem, Singularities and their classification, Riemann's theorem, Limit points of zeros and poles, Casorati-Weierstrass's theorem, behaviour of a function at the point at infinity.
- Theory of residues, Cauchy's residue theorem, evaluation of improper integrals, Argument principle, Rouche's theorem and its applications, Maximum modulus theorems, Schwarz lemma Conformal mappings, Möbius transformation, Principle of symmetry, introduction to Analytic continuation, Monodromy theorem.

Suggested Readings:

Functions of one complex variable, 2nd Ed.,
J. B. Conway,
Narosa Publishing House, New Delhi, 1997.

Theory of complex functions,
R. Remmmert,
Springer-Verlag, New York, 1991.

Complex Analysis- 3rd Edn,
L. V. Ahlfors,
McGraw-Hill, 1979

Complex Variables and applications,
R. V. Churchill and J. W. Brown,
McGraw Hill, 1996.

Theory of Functions of a Complex Variable (Vol. I, II & III),
I. Markushevich,
Prentice-Hall, 1965 & 1967.

The Theory of Functions,
E. C. Titchmarsh,
Oxford University Press, 1939.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester **I** ☑ Semester II ☐ Semester III ☐ Semester IV ☐

Course Name: Ordinary Differential Equations and Special Functions

Course Code: MATH-CC-106

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-106

Course Name: Ordinary Differential Equations and Special Functions

Brief Course Description:

- Review of solution for first order as well as second-order equations, Existence and Uniqueness of Solutions of Initial Value Problems, Green's function and its properties, Lagrange's identity, solution of the equation from the solution of its adjoint equation, self-adjoint equation.
- Homogeneous linear differential equations and their applications, series solution by the method of Frobenius, special functions: hyper-geometric functions, Bessel function Legendre functions and Hankel functions and their properties.
- Systems of first-order equations and the matrix form, autonomous system, critical points, phase plane, stability, asymptotic stability.

Prerequisite(s) and/or Note(s):

Students are assumed to have studied Linear Algebra, Analysis, Geometry and graduate level ordinary differential equation

Course Objectives:

Knowledge acquired:

(1) Solution methods for first and second-order equations

(2) Power series solutions

(3) Properties of Bessel functions and Legendre polynomials

(4) Existence and uniqueness of initial value problems

(5) Picard's and Peano's theorems, Gronwall's inequalit

(6) Maximal interval of existence, continuous dependence

(7) Higher order linear equations and linear systems, fundamental solutions, Wronskian, matrix exponential equations

(8) Boundary value problems for second-order equations, Green's functions, and eigenvalue problems

Skill gained:

(1) Solution method for higher-order equations

(2) Power series solution.

(3) Reducing linear system of equations into matrix differential equation form

(4) Computing Wronskian and fundamental solutions

(5) Constructing Green functions

(6) Solving eigenvalue problems

Competency developed:

(1) Solving higher-order equations, qualitative analysis of special functions
(2) Understanding of linear system of equations,Green's functions, eigenvalue problems

Course Syllabus:

- Review of solution methods for first order as well as second-order equations, Existence and Uniqueness of Solutions of Initial Value Problems, Picard's and Peano's Theorems, Gronwall's inequality, a continuation of solutions, and maximal interval of existence, wellposedness.
- Fundamental solutions, Wronskian, variation of constants, matrix exponential solution, and the behavior of solutions.
- Ordinary differential equations of the Strum Liouville type and their properties, application to Boundary Value Problems, eigenvalues and eigenfunctions, orthogonality theorem, expansion theorem, Green's function, and its properties, Green's function for ordinary differential equations, application to Boundary Value Problems, adjoint equation of n-the order, Lagrange's identity, solution of the equation from the solution of its adjoint equation, self-adjoint equation.
- Homogeneous linear differential equations, fundamental system of integrals, the singularity of a linear differential equation, solution in the neighborhood of a singularity, regular singularity, equation of Fuchsian type, series solution by the method of Frobenius.
- Solution near zero, one, and infinity, integral formula, hypergeometric functions, properties of hypergeometric function.
- Solution of Bessel's equation, Bessel function, and its properties, generating function, integral representation of Bessel's function, Hankel functions, recurrence relations, asymptotic expansion of Bessel functions.
- Solution of Legendre equation, Legendre functions, Generating function, Legendre functions of the first and second kinds, Laplace integral, Legendre polynomials, orthogonality, recurrence relation, Schlaefli's integral.
- Systems of first-order equations and the matrix form, autonomous system, critical points, orbits, trajectories, basic concepts and definitions of phase plane, linearization around critical point, stability, asymptotic stability

Suggested Readings:

Differential Equations,
S. L. Ross,
3rd Edn., Wiley India, (1984).

Differential Equations with Applications and Historical Notes,
G. F. Simmons,
TataMcGrawHill, (2003).

Differential Equations and Their Applications,
M. Brown,
Springer, (1983).

Elementary Differential Equations and Boundary Value Problems,
W. Boyce, R. Diprima,
Wiley, (2009).

Theory of Ordinary Differential Equations,
E. A. Codington,
Dover Publications, (2012).

Special Functions of Mathematical Physics & Chemistry,
I. N. Sneddon,
Oliver & Boyd, London.

Special Functions and their Applications,
N. N. Lebedev,
Dover Publications, (1965).

Special Functions,
E. D. Rainville,
Chelsea Publishing Company, (1971).

Nonlinear Dynamics & Chaos,
S. H. Strogatz,
CRC Press, (2019).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I ☑** Semester II ☐ Semester III ☐ Semester IV ☐

Course Name: Programming Language

Course Code: MATH-DSE-101-

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number:

Course Code: MATH-DSE-101-01

Course Name: Programming Language

Brief Course Description:

Students write programs in some of the languages for examples, C, C++ etc. The languages are used to illustrate programming language constructs such as binding, binding times, data types and implementation, operations (assignment data-type creation, pattern matching), data control, storage management, parameter passing, and operating environment. The suitability of these various languages for particular programming tasks is also covered.

Prerequisite(s) and/or Note(s):

Basic knowledge about computer

Course Objectives:

Knowledge acquired:

(1) Basic ideas about computer programming language

(2) Fundamental data types, operators and expressions, conditional branching used in C

(3) C-functions (declaring and calling a function), arrays (one dimensional and multidimensional), pointers (Accessing array elements through pointers)

(4) Opening and closing a file, reading from a file and writing to a file

Skills gained:

(1) Efficiency in handling with data types, C-operators, expression in C, conditional branching, looping

(2) Construct C-functions, use of Standard C library functions

(3) Efficiency in handling with arrays, pointers, C-file

Competency developed:

(1) Ability to understand syntax in C (data types, arrays, pointers, C-files, C-functions, etc.)

(2) Ability to solve various numerical problems occurring in applied mathematics, theoretical physics, and biological science

Course Syllabus:

- Syntax of programming languages, the semantics of programming languages, procedure-oriented, and object-oriented programming languages, data types, scope, extent, and allocation of storage of variables, statements, blocks, functions, pointers, structures, strings, etc.
- Comparative study of programming languages. Programming in various application areas.

Suggested Readings:

The C programming language,
D. M. Ritchie, B. W. Kernighan, and M. E. Lesk,
Prentice Hall Englewood Cliffs, (1988).

C programming: absolute beginner's guide,
G. M. Perry, and D. Miller,
Pearson Education, (2013).

The Go programming language,
A. Donovan and B. W. Kernighan,
Addison-Wesley Professional, (2015).

Computer Fundamentals and Programming in C,
J. B. Dixit,
Laxmi Publications, Ltd., (2006).

C - In Depth – 2nd Revised Edition,
S.K. Srivastava D. Srivastava,
BPB Publ. (2005).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I☑** Semester II☐ Semester III ☐ Semester IV☐

Course Name: Mathematical skills for problem solving

Course Code: MATH-DSE-101-02

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-101-02.

Course Name: Mathematical skills for problem solving

Brief Course Description:

Basic problems of calculus, real analysis, and set theory with higher degree of difficulty

Prerequisite(s) and/or Note(s):

Graduate level mathematics.

Course Objectives:

Knowledge acquired:

(1) Extension of knowledge gained during undergraduate calculus and analysis courses
(2) Deep understanding of the idea of applying the improvised basic techniques

Skills gained:

(1) To develop techniques to address problems with greater degree of difficulty
(2) To improvise ideas towards applying suitable mathematical approach

Competency developed:

One can create such problems with same degree of difficulty in several topics

Course Syllabus:

20 Problems with higher degree of difficulty from some basic areas of calculus, real analysis, and set theory will be discussed. Students are advised to go through similar problems with same degree of difficulty in practice session.

Suggested Readings:

Problems in Mathematical Analysis I, Real Numbers, Sequences and Series
W.J. Kaczor, M.T. Nowak,
American Mathematical Society

Problems in Mathematical Analysis II, Continuity and Differentiability
W.J. Kaczor, M.T. Nowak,
American Mathematical Society

Problems in Mathematical Analysis III, Integration
W.J. Kaczor, M.T. Nowak,
American Mathematical Society

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: **Semester I☑** Semester II☐ Semester III ☐ Semester IV ☐

Course Name:

Course Code: MATH-AEC-101

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-AEC-101

Course Name:

Brief Course Description:

Prerequisite(s) and/or Note(s):

Course Objectives:

Knowledge acquired:

Skills gained:

Competency developed:

Suggested Readings:

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I☐ **Semester II☑** Semester III ☐ Semester IV☐

Course Name: Modules and Linear Algebra

Course Code: MATH-CC-201

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-201

Course Name: Modules and Linear Algebra

Brief Course Description:

Modules: Modules, Operations on modules, Module homomorphism, Quotient modules, Finitely generated modules, Modules over PID.
Linear Algebra: Minimal polynomial, Invariant subspaces, Diagonalizations, Jordan blocks, Rational canonical form, Quadratic forms, Bilinear forms.

Prerequisite(s) and/or Note(s):

Students are assumed to have studied the matrix, vector space, basis, linear transformation.

Course Objectives:

Knowledge acquired:

(1) Matrix theory, determinants and their application to systems of linear Equations

(2) Eigenvalues, diagonalization of matrices and reduction of systems of linear equations into simpler systems of easily tractable nature

(3) Vector theory: subspace, basis, linear independence, inner product spaces etc.

(4) Applications of matrix algebra

Skills gained:

(1) Matrix manipulations

(2) Handing of systems of linear equations

(3) Use mathematical software to solve problems on linear systems

(4) Ability to go abstract from concrete: from concrete notion of solution spaces to vector spaces

(5) Linear modeling problems

Competency Developed:

(1) Qualitative analysis of systems of linear equations

(2) Qualitative analysis of systems of linear equations

(3) Vector Spaces, linear independence and foundations of abstract algebraic thinking

Course Syllabus:

- Modules over a commutative ring with identity, Submodules, Operations on submodules, Direct sum and Direct product of submodules, Module homomorphisms, Quotient modules, Finitely generated modules, Free modules, Torsion-free modules, Modules over PID, Fundamental structure theorem for finitely generated modules over a PID.
- A arbitrary fields, Quadratic forms, Reduction and classification of quadratic forms, Bilinear forms, Symmetric bilinear forms, Skew symmetric bilinear forms. annihilating polynomials, minimal polynomial, Direct sum decompositions, Invariant subspaces, Primary decomposition theorem, Diagonalization regularizations, Jordan blocks, Jordan forms, Rational canonical form, Generalized Jordan form over anecto.

Suggested Readings:

Linear Algebra,
K. Hauffman, R. Kunz,
Pearson Education (INDIA), 2003.

Linear Algebra and Its Applications,
G. Strang,
4th Edition, Brooks/Cole, 2006.

Linear Algebra,
S. Lang,
Springer, 1989.

Abstract Algebra,
D. S. Dummit, R. M. Foote,
John Wiley and Sons.

Algebra,
T. Hungerford,
Springer GTM.

Topics in Abstract Algebra,
I. N. Herstein,
Wiley Eastern Limited.

Fundamentals of Abstract Algebra,
D. S. Malik, J. N. Mordeson, M. K. Sen,
McGraw-Hill, International Edition, 1997.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ **Semester II☑** Semester III ☐ Semester IV ☐

Course Name: Point-Set Topology

Course Code: MATH-CC-202

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☑

Major (> 50%) ☐

Summary of changes

The following advance topological concepts have been incorporated to this syllabus;

The compact-open topology. Continuity of composition; the evaluation map. Cartesian Products. Application to Identification Topologies. Basis for Z^Y. Compact subsets of Z^Y. Sequential convergence in the c-Topology. Metric Topologies; Relation to the c-Topology. Pointwise convergence. Comparison of Topologies in Z^Y.

Entourages. Expression of uniform continuity, uniform convergence and Cauchy sequences in terms of entourages. Basic properties of the family of all entourages. Uniformities. Uniform spaces. Base and subbase for uniformities. Union and intersection of uniformities. Uniform topology. Uniform continuity. Uniform isomorphism. Uniform covers. Uniform products and subspaces. Uniformizable spaces. Metrizability of uniformity. Complete uniform spaces and completion. Uniformity generated by proximity.

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-202

Course Name: Point-Set Topology

Brief Course Description:

'Point-Set Topology' deals with topics in Point-Set Topology. In particular, the course will cover different type of compactness, locally compact spaces, compactification, para-compact spaces, function spaces, uniform spaces and related topics.

Prerequisite(s) and/or Note(s):

(1) Graduate level mathematics.
(2) Syllabus changes yearly and may be modified during the term itself, depending on the circumstances. However, students will be evaluated only on the basis of topics covered in the course.

Course Objectives:

Knowledge acquired:

(1) Observation of differences between metric space and Topological Space via different kinds of compactness of Topological spaces

(2) Role of ordinals to distinguish different compactness of Topological spaces

(3) Paracompactness of Topological Spaces towards searching stronger to simpler condition for metrizability of Topological Spaces

(4) Local compactness and compactification to embed possible Topological spaces into well behaved compact Hausdorff spaces

(5) Function spaces and Uniform spaces (which placed in between metric space and topological space according to their properties/ behavior)

Skills gained:

(1) Analysis in abstract spaces

(2) Simplifications of proofs or understanding by using compactification

Competency developed:

Ability to learn/understand any topic/subject related to topology

Course Syllabus:

- Compact spaces(recall), sequentially compact spaces, limit point compact spaces, countably compact spaces and their basic properties (continuous image, productivity, hereditary property etc.), relation among themselves. Complete metric spaces and totally boundedness. The Lebesgue number lemma. Coincidence of all above mentioned compactness in metric spaces.
- Local compactness. Product of locally compact spaces. Compactification with special care of Stone-Čech Compactification.
- Locally finiteness. σ-locally finiteness. Refinement. Nagata-Smirnov Metrization Theorem. Paracompactness. Micheal's theorem, Para compactness of metrizable spaces (Stone's theorem), Partition of unity. Locally metrizable spaces. Smirnov metrization theorem.
- The compact-open topology. Continuity of composition; the evaluation map. Cartesian Products. Application to Identification Topologies. Basis for Z^Y. Compact subsets of Z^Y. Sequential convergence in the c-Topology. Metric Topologies; Relation to the c-Topology. Pointwise convergence. Comparison of Topologies in Z^Y.

- Entourages. Expression of uniform continuity, uniform convergence and Cauchy sequences in terms of entourages. Basic properties of the family of all entourages. Uniformities. Uniform spaces. Base and subbase for uniformities. Union and intersection of uniformities. Uniform topology. Uniform continuity. Uniform isomorphism. Uniform covers. Uniform products and subspaces. Uniformizable spaces. Metrizability of uniformity. Complete uniform spaces and completion. Uniformity generated by proximity.

Suggested Readings:

Topology: a first course,
J. R. Munkres
Prentice Hall.

Introduction to Topology and Modern Analysis,
G. F. Simmons
TataMcGraw-Hill.

Basic Topology,
M. A. Armstrong
Springer.

General Topology,
J. L. Kelley
Springer-Verlag.

Topology,
J. Dugundji
UBS.

General Topology,
S. Willard
Dover.

Introduction to general topology,
K. D. Joshi
John Wiley & Sonns, Inc. New York.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester☐ **Semester II ☑** Semester III ☐ Semester IV ☐

Course Name: Functional Analysis

Course Code: MATH-CC-203

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date

Course Code: MATH-CC-203

Course Name: Functional Analysis

Brief Course Description:

Normed spaces, Banach spaces, Fundamental Theorems for Normed and Banach Spaces, Inner Product Spaces, Hilbert Spaces, Adjoint and Different Types of Operators on Hilbert Spaces, Sesquilinear Functionals, Theory of Compact Operators.

Prerequisite(s) and/or Note(s):

Fundamentals of Metric spaces, Linear Algebra and Complex Analysis.

Course Objectives:

Knowledge acquired:

(1) Definition of normed linear spaces, Banach spaces and examples

(2) Quotient space of normed linear spaces, Riesz's Lemma, basic properties of finite dimensional normed linear spaces

(3) Concept of bounded linear operators between these spaces, concept of the spectrum of a bounded linear operator, concept of the dual space of a normed linear space

(4) Uniform boundedness theorem and some of its consequences, open mapping and closed graph theorems

(5) Hahn-Banach theorem for real linear spaces, complex linear spaces and normed linear spaces

(6) Reflexive spaces, Definition of inner product spaces, Hilbert Spaces and examples

(7) Orthonormal sets. Bessel's inequality, complete orthonormal sets and Parseval's identity

(8) Riesz representation theorem, adjoint of an operator on a Hilbert space

(9) Reflexivity of Hilbert spaces, concept of compact, Positive, projection, self-adjoint, normal and unitary operators

Skills gained:

(1) Equivalent norms on a vector space define the same topology

(2) Understanding the differences between Hamel basis and Schauder basis

(3) Using topology to work with infinite dimensional vector spaces

(4) Viewing $C[a, b]$ with sup-norm and integration-norm respectively as Banach space and incomplete norm linear space

(5) Realizing the distinction between Banach and Hilbert spaces

(6) Analyzing the structure of the spectrum of certain operators

Competency developed:

(1) Working with a complete orthogonal set in a Hilbert space

(2) Fredholm and another integral operator as a linear operator

(3) Investigating the best approximation of a given vector by vectors in a given subspace

(4) Computing the dual spaces of certain Banach spaces

(5) Working with weak and weak * topologies on normed linear spaces

Course Syllabus:

- Definitions and examples; spaces likel^p, l^∞, $C[a, b]$, Holder and Minkowski inequalities for sums, completeness of metric spaces, isometric mapping, isometric spaces, completion of metric spaces, Baire category theorem, Banach's fixed point theorem and its applications.
- Normed linear spaces, Banach spaces and examples, quotient space of normed spaces and its completeness, Schauder basis, normed space and its completion, equivalent norms, finite dimensional normed linear spaces and compactness, Riesz Lemma, bounded linear operators, its equivalence with continuity, normed linear spaces of bounded linear operators, linear functional, bounded linear functional, dual space and second dual space, canonical embedding, algebraic reflexivity, strong and weak convergence, uniform boundedness theorem and some of its consequences, open mapping theorem, closed graph theorem, Hahn-Banach theorem for real linear spaces, complex linear spaces and some of its consequences.
- Inner product spaces, Hilbert spaces and examples, Cauchy-Schwarz inequality, triangle inequality, parallelogram law, Inner product spaces and its completion, orthonormal sets and sequences, orthogonal complements and direct sums, Bessel's inequality, Gram-Schmidt orthonormalization process, complete orthonormal sets and Parseval's identity, Riesz representation theorem, Sesquilinear form, separable and non-separable Hilbert space, reflexivity of Hilbert spaces.
- Adjoint of an operator on a Hilbert space, Self-adjoint operators, normal and unitary operators, convergence of sequences of operators and functionals, positive operators, projection operators, compact operators.

Suggested Readings:

Introductory Functional Analysis with Applications,
K. Kreyszig,
John Wiley &Sons New York, 1978.

Elements of Functional Analysis,
B. K. Lahiri,
The World Press Pvt. Ltd. Calcutta, 1994.

Introduction to Topology and Modern Analysis,
G. F. Simmons,
McGraw-Hill Co. New York, 1963.

A course in functional analysis,
J. B. Conway,
Springer-Verlag, New York 1990

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ **Semester II ☑** Semester III ☐ Semester IV ☐

Course Name: Classical Mechanics and Calculus of Variation

Course Code: MATH-CC-204

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑**NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-204

Course Name: Classical Mechanics and Calculus of Variation

Brief Course Description:

Classical Mechanics: Generalized coordinates, degrees of freedom, D'Alembert's principle, constraints, Lagrange's equation of motion, conservation theorems, cyclic coordinates, generalized momentum, Routh's equation Hamilton's variables, Hamilton's canonical equation, Noether's theorem, Hamilton's principle and principle of least action, canonical transformation with different generating functions, Lagrange and Poisson brackets and their properties, Hamilton-Jacobi equations. Calculus of variations: Euler's equation, solutions of Euler's equation, geometrical problems, geodesics, minimum surface of revolution, isoperimetric problems, Brachistochrone problem, Variation problems involving several independent variables, Lagrange's multipliers, moving boundaries, sufficient conditions for extremum, variational formulation of Boundary Value Problem, minimum of quadratic functional, approximate methods, Rayleigh-Ritz method, Galerkin's method.

Prerequisite(s) and/or Note(s):

Students are assumed to have studied under graduate level Mechanics, Calculus, vectors and Differential equations.

Course Objectives:

Knowledge acquired:

(1) Gain knowledge about basic principles of generalized coordinates, degrees of freedom, different type of constraints. Know the Lagrange's equations of motion

(2) Gain knowledge about the relation between Lagrangian and Hamiltonian of a dynamical system.Learn about gauge transformation, point transformation and canonical transformation. Poisson's bracket. Gain knowledge about energy equation in conservation fields

(3) Learn about fundamentals of functionals Understand about the extremum of functionals and curvature of curve

Skills gained:

After completion of the course, students will be able to

(1) Understand constraints of motion and differentiate different type of constraints

(2) Apply Lagrange's equation and Hamilton's canonical equations properly to any physical system (for example: planetary motion)

(3) Apply Hamilton's principle and least action principle to physical problems

(4) Analyze variational problems to deduce key properties of system behavior

(5) Derive equation of extrema of functions of several variables

Competency developed: Students will be able to

(1) Derive solutions of dynamical systems using Lagrange's and Hamiltonian equations
(2) Apply the knowledge of classical mechanics to the study of theory of Relativity, cosmological study, and quantum mechanics

Course Syllabus:

- **Classical Mechanics:** Introduction, generalized coordinates, degrees of freedom, virtual work, D'Alembert's principle, unilateral and bilateral constraints, holonomic and nonholonomic systems, scleronomic and rheonomic systems, Lagrange's equations for holonomic systems, Lagrange's equation for impulsive forces and for systems involving dissipative forces, conservation theorems. cyclic coordinates, generalized momentum.
- Hamilton's variables, Hamilton's canonical equation, homogeneity of space and time, conservation principles, Noether's theorem, Routh's equation, Hamilton's principle and principle of least action, canonical transformation with different generating functions, Lagrange and Poisson brackets and their properties, Hamilton-Jacobi equations, Poisson's identity, Jacobi-Poisson theorem.
- **Calculus of variations:** Introduction, Euler's equation, different forms of Euler's equations, solutions of Euler's equation, geometrical problems, geodesics, minimum surface of revolution, isoperimetric problems, Brachistochrone problem, variational problems involving several unknown functions, functionals dependent on higher order derivatives.
- Variation problems involving several independent variables, constraints and Lagrange's multipliers, moving boundaries, sufficient conditions for extremum, variational formulation of Boundary Value Problem, minimum of quadratic functional, approximate methods, Rayleigh-Ritz method, Galerkin's method, weighted-residual methods, collocation methods, variational methods for time dependent problems.

Suggested Readings:

Classical Mechanics,

H. Goldstein,

Pearson New International edition, Third edition, (2014).

Classical Mechanics,

P. S. Jog, N. C. Rana,

McGraw-Hill, First edition, (2001).

Classical Mechanics,

S. L. Gupta, V. Kumar, H. V. Sharma,

Pragati Prakashan, (2010).

Introduction to Classical Mechanics,

R. G. Takwale, P.S. Puranik,

Tata McGraw-Hill, (1979).

Calculus of Variations with Applications,

A. S. Gupta,

Prentice Hall of India, (2015).

Calculus of Variation, Dover Publication,

L. D. Elsgole,

Inc. New York, (2007).

Calculus of Variation,

M. Gelfand, S. V. Fomin,

Dover books on Mathematics (2000).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester ☐ **Semester II** ☑ Semester III ☐ Semester IV ☐

Course Name: Integral Equations and Integral Transforms

Course Code: MATH-CC-205

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO**☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-205

Course Name: Integral Equations and Integral Transforms

Brief Course Description:

Classifications of integral equations, solutions methods, Hilbert-Schmidt theory of symmetric kernels, construction of Green's function, convoluted kernels, Abel's equations and solutions. Laplace and Fourier transforms, Mellin & Hankel transformation, Bromwich Integral, convolutions and applications, distributions and their transforms, applications to Wave, Heat and Laplace equations.

Prerequisite(s) and/or Note(s): Students are assumed to have studied graduate level calculus, algebra and differential equation

Course Objectives:

Knowledge acquired:

(1) Construction of Green's function.

(2) Concept of various Integral Equations: Fredholm and Voltera type.

(3) Calculus of Variations, Euler-Lagrange's equations.

(4) Convolutions and applications.

(5) Distributions and their transforms.

Skills gained:

(1) Obtain solution of a boundary value problem using integral equations.

(2) Obtain minimum surface of revolution from a variational formulation.

(3) Solution of Wave, Heat and Laplace equations using integral transform technique.

Competency developed:

(1) Solutions of the Abel's Integral Equations.

(2) Handle separable and symmetric kernels of an integral equation.

(3) Applying convolution theorem on the transformed function in order to get the primitive.

Course Syllabus:

- **Integral Equations:** Classifications, successive approximations, separable kernels, Fredholm alternative, Hilbert-Schmidt theory of symmetric kernels, construction of Green's function, convoluted kernels, Abel's equations and solutions.

- **Integral Transforms:** Laplace and Fourier transforms, applications to Boundary Value Problems, Mellin & Hankel transformation, inversion formulae, Bromwich Integral, convolutions and applications, distributions and their transforms, applications to Wave, Heat and Laplace equations.

Suggested Readings:

The Use of Integral Transform,

I. N. Sneddon,

Tata-McGrawHill, (1974).

Fourier Series and Boundary Value Problems,
R. Churchil, J. Brown,
McGraw- Hill, (1978).

Integral Equations,
F. G. Tricomi,
Dover Publications, (1985).

Linear and Nonlinear Integral Equations,
A. M. Wazwaz,
Springer, (2011).

An introduction to Laplace Transforms and Fourier Series,
P. P. G. Dyke,
Springer, (2014).

Laplace Transforms (Schaum's OuTlines series),
M. G. Spiegel,
McGraw-Hill Education, (2002).

The Laplace Transform,
J. L. Schiff,
Springer, (2013).

Integral Transforms and Their Applications,
L, Debnath, D, Bhatta,
CRC Press, (2016)

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ **Semester II ☑** Semester III ☐ Semester IV ☐

Course Name: Partial Differential Equations

Course Code: MATH-CC-206

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-206

Course Name: Partial Differential Equations

Brief Course Description:

Formation and solution of PDE, first-order non-linear PDE, solutions classification, and canonical forms of PDE.Linear partial differential equations of second and higher-order,
Classification of Second-order PDE, canonical forms, and canonical transformation of linear second-order PDE.Derivation of Laplace and Poisson equation, solution of Laplace equation in cylindrical and spherical coordinates, steady-state heat flow equation Problems, Poisson's general solution.Formation and solution of the diffusion equation, initial and boundary conditions. Formation and solution of one-dimensional wave equation, canonical reduction, initial value problem.
Elementary properties of generalized functions, differentiation and other applications of generalized functions, Laplace transform of a generalized function.

Prerequisite(s) and/or Note(s): Calculus, Algebra, and Geometry.

Course Objectives:

Knowledge acquired:

(1) Cauchy problem for 1st order hyperbolic equations, method of characteristics
(2) Classification of 2nd order partial differential equations, normal forms and characteristics
(3) Lagrange-Green's identity, uniqueness by energy methods
(4) Mean value property, weak and strong maximum principle, Green's function, poisson's formula, Dirichlet's principle
(5) Initial value problem for heat equation, fundamental solution, weak and strong maximum principle and uniqueness results
(6) Uniqueness of wave equations, D'alembert's principle, Duhamel's principle.onstruction of Green's function

Skills gained:

(1) Solving Cauchy problem
(2) Solving 1st and 2nd order partial differential equations
(3) Uniqueness of heat and wave equations
(4) Methods of separation of variables for Laplace, heat and wave equationsbtain solution of a boundary value problem using integral equations

Competency developed:

(1) Reduction into canonical form and solving partial differential equations
(2) Solution of heat, wave and Laplace equations

Course Syllabus:

- General solution and complete integral of a partial differential equation, singular solution, integral surface passing through a curve and circumscribing a surface.
- Formation and solution of PDE, integral surfaces, Cauchy's method of characteristic, orthogonal surfaces, First order non-linear PDE, compatible system, Charpit's method, classification and canonical forms of PDE.
- Linear partial differential equations of second and higher order, classification of Second order PDE, Monge's method. reduction to canonical form, solution of equations with constant coefficients by (i) factorization of operators (ii) separation of variables, linear PDE with variable coefficients, canonical forms, canonical transformation of linear second order PDE.
- Derivation of Laplace and Poisson equation, Boundary Value Problem, Harmonic functions, characterization of harmonic function by their mean value property, method of separation of variables for the solutions of Laplace's equations, Dirichlet Problem and Neumann Problem for a rectangle, interior and exterior Dirichlet problems for a circle and a semi-circle, interior Neumann problem for a circle, solution of Laplace equation in cylindrical and spherical coordinates, steady-state heat flow equation Problems, Poisson's general solution, examples.
- Formation and solution of diffusion equation, initial and boundary conditions, separation of variables method, solution of heat equation under Dirichlet and Neumann condition, heat conduction problem for an infinite rod, heat conduction in a finite rod, solution of parabolic equation under non-homogeneous boundary condition, solution of diffusion equation in cylindrical and spherical coordinates, examples.
- Formation and solution of one-dimensional wave equation, canonical reduction, initial value problem, D'Alembert's solution, vibrating string, forced vibration, method of separation of variables, initial value problem and boundary value problem for two-dimensional wave equation, initial value problem for a non-homogeneous wave equation, higher-dimensional wave equations, periodic solution of one-dimensional wave equation in cylindrical and spherical coordinate systems, vibration of circular membrane, uniqueness of the solution for the wave equation, Duhamel's Principle, examples.
- Elementary properties of generalized functions, addition, multiplication, transformation of variables, generalized function as the limit of a sequence of good functions, even and odd generalized functions, differentiation and integration of generalized functions, simple examples, ordinary function as generalized function, Anti-derivative, regularization of divergent integral with simple example, Fourier transform of generalized function, examples, convergence of a sequence of generalized functions with examples, Laplace transform of generalized function.

Suggested Readings:

Elements of Partial Differential Equations,
I. N. Sneddon,
McGraw-Hill, (1986).

Partial Differential Equations,
L. C. Evans,
Graduate Studies in Mathematics, Vol. 19, American Mathematical Society, (1998).

Partial Differential Equations,
R. C. McOwen,
(Pearson Edu.), (2003).

Partial Differential Equation,
T. Amarnath,
Alpha Science International, (2003).

Partial Differential Equations,
P. P. Prasad, R. Ravichandan
Wiley Eastern, (1985).

Introduction to the Theory of Partial Differential Equations,
M. G. Smith,
Van Nostrand, (1967) .

Partial Differential Equations,
F. H. Miller,
Wiley, New York, (1941).

Fourier Series & Boundary Value Problems,
Churchil, J. Brown,
McGraw-Hill, New York, (1987).

Introduction to Partial Differential Equations,
G. Greenspan,
Dover Publications, (2012).

Generalized Functions,
D. S. Jones,
Cambridge University Press, (1982)

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester ☐ **Semester II☑** Semester III ☐ Semester IV ☐

Course Name: Mathematical Type-setting, Report writing and Seminar Presentation

Course Code: MATH-DSE-201-01

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core c

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Name: Mathematical Type-setting, Report writing and Seminar Presentation

Course Code: MATH-DSE-201-01

Brief Course Description:

LATEX, a document preparation system, is widely used for publishing in many scientific fields like mathematics, statistics, computer science, engineering, chemistry, physics, economics, linguistics, etc. It is a powerful and open-source system that provides numerous facilities for automating typesetting of the document: i.e. structuring page layout, listing and auto-numbering of sections, tables, figures, generating a table of contents, managing cross-referencing, citing, and indexing.

Prerequisite(s) and/or Note(s): None

Course Objectives:

Knowledge acquired:

(1) Handle different types of documents

(2) Organize documents into different sections, subsections, etc.

(3) Formatting pages (margins, header, footer, orientation)

(4) Formatting text

Skills gained:

(1) Write complex mathematical formulae

(2) Include tables and images

(3) Cross-referencing, bibliography, and Indexing

(4) Read error messages as and when required

(5) Create presentations using Beamer

Competency developed:

(1) Student knows history of Latex and how to install Latex software

(2) Student learns to write equations, matrix and tables

(3) Student learn to quote the references, equation references, citations

(4) Student lists the figures, tables and generating index

Course Syllabus:

- **Historical background of LATEX and its pronunciation:** Creating a new document, Opening and saving a Doument, Use of document classes like article.cls, amsart.cls, books.cls, report.cls; Adding packages like amssymb, amsmath, amsthm, amsfonts, graphics, graphix, times; Entering Text, Editing Text Entering and Editing Mathematics: Entering Mathematical Characters, Entering Mathematical Objects, Entering Mathematics with Fragments, Using Body Math, Editing Mathematics Formatting Your Document: Formatting with tags: theorem, definition, corollary, lemma, proposition, example, acknowledgement, axiom, proposition and changing their styles; Formatting the Page, Changing body text point size, paper size, orientation, title page, two column category, equation number position;

- **Use of unit of measurement:** ex, em, pt, cm, mm, in; Definition of commands : \newcommand, \renewcommand, \setcounter, \addcounter, \newenvironment, \renewenvironment;
- **Introduction to spacing:** horizontal spacing, vertical spacing, small space, big space etc; Different pagebreaks: newline, line break; Making section, subsection etc, Alignment of texts, pictures, creating post script files (*.ps, *.eps) and inserting them into Tex files.
- **Previewing and Printing Your Document:** Creating PDF Files, Exporting Documents as HTML Files. Typesetting Your Document using MS word and LaTeX: Understanding the Typesetting Process, Typeset Previewing and Typeset Printing, Understanding the Appearance of Typeset Documents, Creating Typeset Document Elements, Creating Cross-References, Creating Notes, Creating Bibliographies and Citations, Obtaining More Information about Typesetting

Suggested Readings:

A document preparation system

Leslie Lamport

Addison Weseley Publisher Company, 1994

LaTeX Beginner's Guide

Stefan Kottwitz

Getting Started with LaTeX

David R. Wilkins

LaTeX for Beginners: Workbook

[Available at http://www.docs.is.ed.ac.uk/skills/documents/3722/3722- 2014.pdf]

LaTeX Tutorials A PRIMER Indian TEX Users Group Trivandrum, India 2003 September
Edited by E. Krishnan

[Available at https://www.tug.org/twg/mactex/tutorials/ltxprimer-1.0.pd]

LaTeX Wikibooks.org/wiki/Latex

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester ☐ **Semester II☑** Semester III ☐ Semester IV☐

Course Name: Social Outreach Programme

Course Code: MATH-DSE-201-02

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES**☑ NO ☐

Is the course based on Activity ? YES ☐ **NO**☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Name: Social Outreach Programme

Course Code: MATH-DSE-201-02

Brief Course Description:

This course is on activity based where student will carry out the programme at their own. On the direction of department, each student will be given an opportunity to take class (4 to 5 classes) in the surrounding institutes on a school level topic of his/her own choice in the field of Mathematics and its applications. At the end of the course, students have to submit a report of their work with the lesson plan on the topic of their choice to the department.

Prerequisite(s) and/or Note(s):

Under graduate level mathematics

Course Objectives:

Objective of this course is to give an opportunity to experience of teaching and to do some social service.

Knowledge acquired:

To inculcate basic mathematical sense to school children

Skills gained:

To interact with the young minds

Competency developed:

To serve the society in the way of teaching-learning process

Course Syllabus:

This course is on activity based where student will carry out the programme at their own. On the direction of department, each student will be given an opportunity to take class (4 to 5 classes) in the surrounding institutes on a school level topic of his/her own choice in the field of Mathematics and its applications. At the end of the course, students have to submit a report of their work with the lesson plan on the topic of their choice to the department.

Suggested Readings:

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester ☐ **Semester II☑** Semester III ☐ Semester IV ☐

Course Name:

Course Code: MATH-AEC-201

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-AEC-201

Course Name:

Brief Course Description:

Prerequisite(s) and/or Note(s):

Course Objectives:

Knowledge acquired:

Skills gained:

Competency developed:

Suggested Readings:

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Differential Geometry and Its Applications

Course Code: MATH-CC-301

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

No changes made

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-301

Course Name: Differential Geometry and Its Applications

Brief Course Description:

Basics of vectors, 1-forms, Tensors, Manifold, Geometry of space curves, Geometry of surfaces, Geodesic and curvature.
Inertial frame, Lorentz transformation and its consequences, Relativistic mechanics, Minkowskian 4D space-time, 4-vectors, Null vectors, light cone, equivalence of mass and energy.

Prerequisite(s) and/or Note(s): The students are assumed already to have studied undergraduate level Algebra, Calculus, Euclidean vector calculus and geometry, Elementary ordinary and partial differential equations and Newtonian mechanics.

Course Objectives:

Knowledge acquired:

Students will be able to gain the following knowledge of

(1) Vectors, 1-forms, Manifolds, Tensors and their differentiability, Connections, connection forms

(2) Different type of curves in 3D spaces, Differentiable functions on surfaces, Differentiable maps on regular surfaces, Curves on surfaces, Geodesics and curvature

(3) Inertial frame of reference, Lorentz Transformation, world line, world events, Proper time, relativistic mass and energy, Equivalence of mass and energy, Geometry of Minkowskian 4D space-time

Skills gained:

After completion of the course, basic mathematical skill gained

(1) to study different curves and surfaces and their natures

(2) to solve the problems related to curves, surfaces, geodesics, curvature and their implications in real life problems

(3) to prepare for more advanced study and apply this knowledge to physical problems and Engineering sciences

Competency developed:

Students will be able to link between physical world and its visualization by studying the Differential geometry course. Students will also be able to think about 4D space-time world and apply relativistic mechanics to real life situations

Course Syllabus:

- Vectors, one-forms (dual vectors), manifolds, differentiable manifolds and tensors, metric tensor on manifolds, differential forms: Hodge duality, differential structure on manifold: Lie derivative, Exterior differentiation, affine connection, Covariant differentiation and Intrinsic differentiation; Absolute differentiation: connection forms, Lie bracket, Holonomic and Anholonomic bases.

- Geometry of space curve: Serret-Frenet formulae, Equation of Straight lines, Helix, Bertrand curve.
- Geometry of surfaces: regular surfaces, differential functions on surfaces, the tangent plane and the differential maps between regular surfaces, the first fundamental form, normal fields and orientability, Gauss map, the second fundamental form, normal and principal curvatures, Gaussian and mean curvatures.
- Geodesic and curvature: autoparallel curves and geodesics, Exponential map, Parallel transport, geodesic coordinates, curvature, Riemann curvature tensor and Theorem of Egregium, geodesic curvature, Ricci tensor, Ricci scalar, Curvature 2-forms, geodesic deviation, Bianchi identities.
- Relativistic mechanics: Inertial frame of references, postulates of special theory of relativity, Lorentz transformation from geometric point of view; consequences of Lorentz transformation: length contraction, time dilation; laws of composition of velocities, relativistic mechanics: world line, world events and world region, proper time as an invariant arc length, relativistic mass and energy and momentum, equivalence of mass and energy; the space-time geometry: Minkowskian 4D space-time, four-vector, time-like, light-like and space-like vectors, light cone, time-like, space-like, light-like intervals, null cone.

Suggested Readings:

Elementary Differential Geometry,
C. Bar,
Cambridge University Press, 2011.

Differential Geometry of Curves and Surfaces,
K. Tapp,
Springer,2016.

Elementary Differential Geometry,
A. Pressley,
Springer, 2010.

Differential Geometry of Curves and Surfaces,
M. P. Do Carmo,
Prentice- Hall, Inc., Upper Saddle River, New Jersey 07458, 1976.

Differential Geometry of Curves and Surfaces,
S. Chakraborty,
A Treatise on Differential Geometry and its role in Relativity Theory,
Book ref: arXiv:1908.10681[gr-qc] (2019).

Introduction to Special Relativity,
R. Resnick,
Wiley Student Edition, 1968.

An Introduction to Relativity,
J. V. Narlikar,
Cambridge University Press, 2010.

Introduction to General Relativity,
L. Ryder,
Cambridge University Press, 2009.

A First Course in GENERAL RELATIVITY,
B. F. Schutz,
Cambridge University Press, 2009.

Space-time and Geometry,
S. M. Carroll,
Cambridge University Press, 2019.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III**☑ Semester IV ☐

Course Name: Field Extension and Galois Theory

Course Code: MATH-CC-302

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-302

Course Name: Field Extension and Galois Theory

Brief Course Description:

Field Extension: Algebraic and transcendental extensions, splitting fields, algebraically closed fields, Separable extensions, Normal extensions, Finite fields.
Galois Theory: Galois Extensions, Galois Groups, Cyclotomic extensions.

Prerequisite(s) and/or Note(s): Students are assumed to have study groups, rings, fields and linear algebra

Course Objectives:

Knowledge acquired:

(1) Concept of algebraic element, transcendental elements, minimal polynomials etc.

(2) Various field extensions, e.g. splitting fields, algebraically closed fields, perfect fields, normal fields, separable fields, cyclotomic fields etc.

(3) Concept of Galois groups and Galois extensions

Skills gained:

(1) Construction of minimal polynomials, splitting fields, finite fields etc.

(2) Verify/identify normal fields, separable fields

(3) Construction of algebraic numbers geometrically using straightedge and compass only

(4) Formulation of Galois groups and Galois field extensions

Competency developed:

(1) Relate Structures of fields with certain related groups

(2) Abel's famous theorem on the insolvability of the general quintic polynomials

Course Syllabus:

- Fields, Algebraic and transcendental extensions, finite extensions, fundamental theorem of general algebra (Krönekar Theorem), Splitting fields, algebraically closed fields, Separable and Purely inseparable extensions, Perfect fields, Normal extensions, Finite fields.
- Galois Extensions, Galois Groups, Fundamental theorem of Galois theory, Cyclotomic extensions, Solvability by radicals, Geometric constructions by straightedge and compass only.

Suggested Readings:

Fundamentals of Abstract Algebra,
D. S. Malik, J.M. Mordeson, and M.K. Sen,
McGrawHill, International Edition, (1997).

Abstract Algebra (3e),
D. S. Dummit and R.M. Foote,
John Wiley and Sons (Asian reprint).

Algebra,
S. Lang,
Springer, 3rd edition, (Indian reprint 2004).

Topics in Algebra,
N. Herstein,
Wiley Eastern Ltd. (1975).

A First Course in Abstract Algebra,
J. B. Fraleigh,
Narosa Publishing House.

Algebra,
M. Artin,
Prentice Hall.

Algebra, Vol. IV - Field Theory,
I. S. Luther and I.B.S. Passi,
Narosa Publishing House.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Continuum Mechanics

Course Code: MATH-DSE-301-01

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-01

Course Name: Continuum Mechanics

Brief Course Description:

Studying wellposedness of solution of a partial differential equation using the theories related different functional spaces in particular, sobolev spaces.

Prerequisite(s) and/or Note(s): Students are assumed to study tensor calculus, basic linear algebra, mechanics, fluid mechanics and solid mechanics.

Course Objectives:

Knowledge acquired:

(1) Be familiar with linear vector spaces relevant to continuum mechanics and able to perform vector and tensor manipulations in Cartesian and curvilinear coordinate systems

(2) Be able to describe motion, deformation and forces in a continuum

(3) Be able to derive equations of motion and conservation laws for a continuum

(4) Define the stress tensor and derive it for ideal and Newtonian fluids

(5) Explain the model of linear elasticity

Skills gained:

(1) Understand constitutive models for fluids and viscoelastic solids

(2) Be able to solve simple boundary value problems for fluids and solids, apply the tensor formalism, treat general stresses and deformations in continuous materials

(3) Give models for simple motion in ideal and viscous fluids and analyze these.

Competency developed:

(1) Explain the difference between Eulerian and Lagrangian definition of the equations of motion

(2) Derive conservation laws for mass, momentum, and energy on local and global form formulate and solve specific technical problems of displacement, strain and stress, perform experiments with stresses and deformations.

(3) Model and analyses the stresses and deformations of simple geometries under an arbitrary load in both solids and liquids.

Course Syllabus:

- Mathematical preliminaries: vector spaces, index notation, second order tensors: skew symmetric, orthogonal and symmetric tensors, invariants of second-order tensors, eigenvalue problem, positive definiteness and polar decomposition theorem, isotropic functions, and higher-order tensors; directional derivative, Frechet derivative, gradient, divergence, curl, and integral theorems, transport theorem, configurations of a body, displacement, velocity, motion, deformation gradient, rotation, stretch, strain, strain rate, spin tensor, assumption of small deformation and small strain. Lagrangian and Eulerian description, deformation gradient, strain tensor, stretch tensors, area and volume transformation, material and spatial derivative, rate of deformation and spin tensors, Reynold's transport theorem, vorticity and circulation.

- Balances of mass, linear momentum and angular momentum, contact forces and the concept of stress, balance of energy and Clausius-Duhem inequality, constitutive relations, frame indifference, material symmetry, kinematic constraints (incompressibility), thermodynamical restrictions.
- Constitutive relations, incompressible fluids, non-Newtonian fluid, boundary value problem.
- Hyper-elasticity, isotropy, linear elasticity, simple constitutive relations, boundary value problem.

Suggested Readings:

An Introduction to Continuum Mechanics (Second edition),
J. N. Reddy,
Cambridge University Press.

Introduction to Continuum Mechanics (Third edition),
Rubin, E. Krempl, W. Michael Lai,
Pergamon press, (1993).

Continuum Mechanics: Concise Theory and Problems (Second Edition),
P. Chadwick,
Dover Publication Inc. (1999).

Fundamentals of Continuum Mechanics,
J. W. Rudnicki,
John Wiley & Sons, (2014).

Continuum Mechanics,
A. J. M. Spencer,
Dover Publication Inc. (2004).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Advanced Partial Differential Equations

Course Code: MATH-DSE-301-02

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-02

Course Name: Advanced Partial Differential Equations

Brief Course Description:

Partial Differential Equations (PDEs) occur frequently in many areas of mathematics. This course extends earlier work on PDEs by presenting a variety of more advanced solution techniques together with some of the underlying theories.

Prerequisite(s) and/or Note(s): Students are assumed to study calculus, partial differential equation

Course Objectives:

Knowledge acquired:

(1) Understand the concept of well-posedness

(2) Understand the existence of weak solutions and shocks

(3) Understand and apply the basic concepts of partial differential equations and the related initial-boundary value problems

(4) Understand and apply fundamental solutions and other representations for solutions of PDEs

(5) Understand weak derivatives, weak solutions, and the concept of Sobolev spaces

Skilled gained:

(1) Solve linear PDEs with the concept of the fundamental solution method

(2) Show logical thinking in problem-solving

(3) Understand and apply numerical methods for the solution of PDEs and the related initial-boundary value problems

Competency developed:

(1) Demonstrate knowledge and understanding of partial differential equations and how they relate to different modeling situations

(2) Understand the concept of the symbol of a PDE and the resulting classification of PDEs

(3) Apply specific methodologies, techniques, and resources to conduct research and produce innovative results in the area of specialization

(4) Interpret solutions in a physical context, such as identifying traveling waves, standing waves, and shock waves

Course Syllabus:

- Hamilton–Jacobi Equation, Hopf–Lax Formula, Euler–Lagrange Equations, Legendre Transformation
- Generalized Solution and Rankine–Hugoniot (R–H) Condition, Lax–Oleinik Formula, Generalized Solution, and Uniqueness, Riemann Problem.
- Definition, non-characteristic Cauchy Problem, Classification of Linear Equations: second and higher orders
- Fundamental Solution, Mean Value Formula and Maximum Principles, Mean Value Formula, Maximum and Minimum Principles, Uniqueness and Regularity of the Dirichlet

Problem, Green's Function and Representation Formula, MVP Implies Harmonicity, Existence of Solution of Dirichlet Problem (Perron's Method), Poisson Equation and Newtonian Potential, Hölder Continuous Functions, Hilbert Space Method: Weak Solutions, Fourier Method.

- Solution in Higher Dimensions, Uniqueness, Inhomogeneous Equation, Maximum and Minimum Principles, Heat Equation on a Finite Interval: Fourier Method, Prescribed Non-zero Boundary Conditions, Free Exchange of Heat at the Ends.
- Cauchy Problem on the Line, Cauchy Problem in a Quadrant, Wave Equation in a Finite Interval, Notion of a Weak Solution, some examples, Wave Equation in Higher Dimensions: Three-Dimensional Wave Equation: Method of Spherical Means, Two-Dimensional Wave Equation: Method of Descent, Telegraph Equation, Wave Equation for General n, Solution Formula via Euler–Poisson–Darboux Equation, Mixed or Initial Boundary Value Problem, General Hyperbolic Equations and Systems.
- Cauchy–Kovalevsky Theorem, Real Analytic Functions, Non-characteristic Cauchy Problem, A Generalization: Application to First-Order Systems, Holmgren's Uniqueness Theorem
- Elementary discussions on Weak Derivatives, Sobolev Spaces and Weak Formulation: Weak Derivatives, Existence of an L^2 Weak Solution, Constant Coefficient Operators, Sobolev Spaces.

Suggested Readings:

Topics in functional analysis and applications,
S. Kesavan,
Wiley eastern, 1989.

Partial Differential Equations (second edition),
L. C. Evans,
AMS, Berkeley, 2010

An Introduction to Partial Differential Equations,
M. Renardy, R. C. Rogers,
Springer, 2004.

Functional analysis, Sobolev spaces, and Partial differential equations,
H. Brezis,
Springer, 2011

Partial Differential Equations Classical Theory with a Modern Touch,
A. K. Nandakumaran, P. S. Datti,
Cambridge University Press, 2020

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Computational Partial Differential Equations

Course Code: MATH-DSE-301-03

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-03

Course Name: Computational Partial Differential Equations

Brief Course Description:

Numerical methods for boundary value problems (BVP); extension to separable elliptic PDEs, fast solvers; irregular domains, variable coefficients; iterative methods; diffusion equations; error analysis; variable coefficients in nonlinear problems.

Prerequisite(s) and/or Note(s): Students are assumed to study numerical analysis, partial differential equation, calculus

Course Objective:

Knowledge acquired:

(1) Finite Difference Methods (forward, backward and central), convergence and consistency, matrix method for stability

(2) Parabolic PDE: Solution for one dimensional equation, explicit and various implicit schemes: stability and convergence of above schemes, extension to 2d parabolic equations.

(3) Elliptic PDE: Solution of Laplace, Poisson etc. PDE in Cartesian and Polar system, ADI and SOR schemes etc.

(4) Hyperbolic PDE: Finite difference explicit and implicit schemes-Upwind scheme, stability analysis, method of characteristics and their significance.

Skills gained:

(1) Convergence estimates for smooth and non-smooth initial conditions, convergence estimate for parabolic differential equations, and matrix method for stability.

(2) Crank-Nicolson scheme (CNS) etc., tri-diagonal system, discussion on compatibility, stability and convergence.

(3) Laplace equation using standard five-point formula and diagonal five-point formula, methods for solving diagonal systems, treatment of irregular boundaries.

(4) Finite Element Method, Finite Volume Method.

Competency developed:

(1) Convergence estimates for smooth and non-smooth initial conditions, convergence estimate for parabolic differential equations, Laxwell-posed and stable initial BVP, matrix method for stability.

(2) Compatibility, stability and convergence of above schemes, extension to 2d parabolic equations.

(3) Solution of Laplace, Poisson etc. PDE in Cartesian and Polar system, ADI and SOR schemes etc.

(4) Finite difference explicit and implicit schemes-Upwind scheme.

Course Syllabus:

- Classifications of PDE, finite Difference Methods (forward, backward and central), convergence and consistency, CFL number and Fourier and Von Neumann stability analysis for Finite Difference Method, theory of well-posed IVPs scalar and systems, convergence estimates for smooth and non-smooth initial conditions, convergence estimate for parabolic differential equations, Lax-Richmyer equivalence theorem, well-posed and stable initial BVP, matrix method for stability.
- Solution for one dimensional equation, explicit and various implicit schemes: Backward in time centered in space (BTCS), Forward in time centered in space (BTCS), Crank-Nicolson scheme (CNS) etc., tri-diagonal system, discussion on compatibility, stability and convergence of above schemes, extension to 2d parabolic equations examples. Constitutive relations, incompressible fluids, non-Newtonian fluid, boundary value problem.
- Solution of Laplace, Poisson etc. PDE in Cartesian and Polar system, ADI and SOR schemes etc., Laplace equation using standard five point formula and diagonal five point formula, methods for solving diagonal systems, treatment of irregular boundaries.
- Wave equation, Finite difference explicit and implicit schemes-Upwind scheme, Lax-Wendroff schemes, MacCormak schemes, stability analysis, method of characteristics and their significance. Introduction to Finite Element Method, Finite Volume Method.

Suggested Readings:

Computational Methods for Partial Differential Equations (Second edition),
M. K. Jain, S. R. K. Iyenger, R. K. Jain,
New Age International Publication (P) Ltd, (2016).

Numerical Solution of Partial Differential Equations (Second edition),
K. W. Mortons, D. F. Mayers,
Cambridge University Press.

Numerical Methods for Partial Differential Equations**,**
V. Ruas,
An Introduction, Wiley, (2016).

Numerical Methods for Partial Differential Equations 1st Edition,
S. Mazumder,
Academic Press, USA.

Department Name:	Mathematics
Program Name:	PG in Mathematics
Program Code:	

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name:	Non-linear Partial Differential Equations
Course Code:	MATH-DSE-301-04
Course Credit:	2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-04

Course Name: Non-linear Partial Differential Equations

Brief Course Description:

The aim of this course is to provide an introduction to modern methods for studying nonlinear partial differential equations. The content of the course, which can change from time to time, is built around some of the following themes: calculus of variations, nonvariational techniques, weak convergence techniques, Hamilton-Jacobi(-Bellman) equations and the theory of viscosity solutions, systems of conservation laws and the theory of shock wave solutions.

Prerequisite(s) and/or Note(s): Students are assumed to study calculus of variation, mechanics and PDE

Course Objectives:

Knowledge acquired:

(1) Understand first order non-linear equations and method of characteristics

(2) Be exposed to conservation laws and shock waves and their solutions

(3) Understanding of some modern methods for studying nonlinear partial differential equations.

(4) Solve advanced mathematical problems using analytical methods

Skills gained:

Using techniques based on maximum principles, being able to treat questions of existence, uniqueness and qualitative properties for nonlinear partial differential equations of interest for geometric problems such as equations of prescribed curvature and minimal surfaces and for physical problems such as potential flows and optimal transport.

Competency developed:

(1) Deepen a modern study of the field of partial differential equations in a nonlinear context by way of techniques based on maximum principles for obtaining pointwise information.

(2) Model real-world problems mathematically and analyze those models using their proficiency of the core concepts.

Course Syllabus:

- First-order nonlinear equations and their applications, Charpit's method, the generalized method of characteristics, complete integrals of certain special nonlinear equations, the Hamilton-Jacobi equation, and its applications.
- Non-linear model equations and variational principles, basic concepts and definitions, some nonlinear model equations, variational principles and the Euler-Lagrange equations, the variational principle for nonlinear Klein-Gordon equations.
- Conservation laws and shock waves, conservation laws, discontinuous solutions, and shock waves, weak or generalized solutions.

Suggested Readings:

Nonlinear Partial Differential Equations for Scientists and Engineers,
L. Debnath,
Springer, 2nd Ed., 2005.

An Introduction to Non-linear Partial Differential Equations,
J. D. Logan,
John Wiley and Sons, 2010.

Partial Differential Equations,
L. C. Evans,
Vol.19, American Mathematical Society, 2nd Ed., 2010.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester ☐ Semester II ☐ Semester III ☑ Semester IV ☐

Course Name: Dynamical System

Course Code: MATH-DSE-301-05

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO**☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-05

Course Name: Dynamical Systems

Brief Course Description:

Discrete and continuous time dynamical systems, orbits, fixed points.
General solution of continuous time linear systems, phase space diagrams, nature of fixed points.
Lyapunov and asymptotic stability, local and global stability, Hartmann-Grobman theorem, Lyapunov functions, periodic orbits, limit cycles, attracting and invariant set, Poincare-Bendixson theorem, Poincare map. Sensitive dependence on initial conditions (SDIC), chaos, invariant measure, Ergodic maps, invariant measure for logistic maps. Symbolic dynamics, shift map, properties of logistic map.
Bifurcation Theory: Saddle-node bifurcation, Pitchfork bifurcation, period doubling bifurcation, period doubling route to chaos, Hopf bifurcation, Sarkovskii's theorem, period-three implies chaos for 1-D maps, two-dimensional maps.

Prerequisite(s) and/or Note(s): The students are assumed to have studied Linear algebra, geometry and differential equations.

Course Objective:

Knowledge acquired:

Upon completion of the course, the students will be able to gain the knowledge of

(1) Definition of autonomous system, critical points, phase space
(2) Local and global stability, Lyapunov functions, periodic orbits, limit cycles, attracting and invariant set, Poincare-Bendixson theorem and Poincare map.
(3) Logistic map properties of logistic map, topological conjugacy of logistic and shift map, chaotic behaviour of logistic map.
(4) Bifurcation, Saddle-node bifurcation, Pitchfork bifurcation, period doubling bifurcation, period doubling route to chaos, Hopf bifurcation.

Skills gained:

Students should be able to

(1) Find out fixed points from autonomous system, to find out the nature of critical points, and to draw the corresponding phase portrait of the system.
(2) Check the stability of the critical points by the Hartmann-Grobman theorem, Lyapunov theorem.
(3) Check the global stability and to draw Poincare map.
(4) To differentiate stable and unstable point by applying Bifurcation theory.

Competency developed:

After completion of the course, the students will be able to

(1) Compute the qualitative behavior of the system without solving analytically.
(2) To convert physical or biological problems in autonomous system and to get a complete evolutionary picture in the phase space.

Course Syllabus:

- Discrete and continuous time dynamical systems, flows and maps, phase space, orbits, fixed points, periodic points and their stability, attractors and repellors, logistic map, tent map, Baker's map, graphical analysis of orbits of one-dimensional maps, hyperbolicity.
- General solution of continuous time linear systems, phase space diagrams, fixed point analysis, stable and unstable nodes, saddle point, stable and unstable foci, centre.
- Lyapunov and asymptotic stability, local and global stability, Hartmann-Grobman theorem, Lyapunov theorem on stability, Lyapunov functions, periodic orbits, limit cycles, attracting and invariant set, Poincare-Bendixson theorem, Poincare map.
- Sensitive dependence on initial conditions (SDIC), topological transitivity, topological mixing, topological conjugacy and semi-conjugacy for maps, chaos, chaotic orbits, Lyapunov exponents, invariant measure.
- Ergodic maps, invariant measure for logistic maps.
- Symbolic dynamics, shift map, properties of logistic map, topological conjugacy of logistic and shift map, chaotic behaviour of logistic map.
- Saddle-node bifurcation, Pitchfork bifurcation, period doubling bifurcation, period doubling route to chaos, Hopf bifurcation, Sarkovskii's theorem, period-three implies chaos for 1-D maps, two-dimensional maps.

Suggested Readings:

Differential Equations and Dynamical Systems,
L. Perko,
Springer, (2001).

Introduction to Apllied Non-Linear Dynamical Systems and Chaos,
S. Wiggins,
Springer New York, (1990).

Nonlinear Dynamics and Chaos,
S. H. Strogatz,
CRC Press, (2018).

Differential Equations, Dynamical Systems,
M. W. Hirsch and S. Smale,
AcademicPress (1974).

Differential Equations, 3rd Edn.,
S. L. Ross,
Wiley India, (1984).

An Introduction to Dynamical Systems,
G. C. Layek, S
pringer, (2015).

Differential Equations, Dynamical Systems and an Introduction to Chaos,
M. W. Hirsch, S. Smale, and R. L. Devaney,
Academic Press, (2012).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III** ☑ Semester IV

Course Name: Fluid Mechanics

Course Code: MATH-DSE-301 -06

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO**☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-06

Course Name: Fluid Mechanics

Brief Course Description:

This course develops concepts in quantum mechanics such that the behavior of the physical universe can be understood from a fundamental point of view. It provides a basis for further study of quantum mechanics.
Content will include: Review of the Schrodinger equation, operators, eigenfunctions, compatible observables, infinite well in one and three dimensions, degeneracy; Fourier methods and momentum space; Hermiticity; scalar products of wave functions, completeness relations, matrix mechanics; harmonic oscillator in one and three dimensions; sudden approximation; central potentials, quantization of angular momentum, separation of radial and angular variables, spherical harmonics, hydrogen atom, spin.

Prerequisite(s) and/or Note(s): Students are assumed to have studied Partial Differential Equations, Classical Mechanics

Course Objectives:

Knowledge acquired:

(1) Understand the basic concepts in fluid mechanics
(2) Understand and apply the conservation laws
(3) Familiarize with vortex dynamics, velocity potential and stream functions
(4) Understand the importance of dimensional analysis

Skills gained:

(1) Derive equation of continuity and to solve problems on steady and unsteady flow
(2) Derive equation of motion of fluid in different forms and to understand the fluid flow in different geometries
(3) Solve problems on two dimensional flows with source, sink and doublets
(4) Derive and solve problems on steady, viscous flow
(5) Derive Navier-Stoke's equation and to analyze problems on instability

Competency developed:

(1) Acquiring linear stability analysis of benchmark problems in fluid mechanics
(2) Model and analyses problems on two-dimensional fluid flow problems
(3) Analyze and solve practical problems on steady, unsteady and incompressible flows

Course Syllabus:

- Continuum hypothesis, Lagrangian and Eularian description, stream lines, path lines, streak lines, vortex lines, velocity potential, vorticity vector, equation of continuity.
- Pressure at a point in a moving fluid, conditions at boundary, Euler's equations of motion, Bernoulli's equation, potential flows, two-dimensional flows: Sources, sinks, doublets, images in rigid infinite plane and in solid sphere, Weiss' sphere theorem, Butler's sphere theorem, flows involving axial symmetry, Stokes stream function, complex velocity potential for two dimensional irrotational-incompressible flows, two-dimensional image systems, Milne-Thomson circle theorem and its applications, Blasius theorem.

- Stress analysis in fluid motion, relations between stress and rate of strain, constitutive equations, derivation of Navier-Stokes equations, exact solutions of Navier-Stokes equations: plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between two concentric rotating cylinders, Stokes first and second problem, viscous flow past a sphere, Reynolds number, Prandtl's boundary layer theory, Karman's integral equation, similarity solution, boundary layer for an axially symmetric flow, laminar flow with adverse pressure gradient and separation. Slow viscous flow: Stokes and Oseen's approximation, theory of hydrodynamic lubrication.
- Linear stability of plane Poiseuille flow, Orr-Sommerfeld equation, description of turbulent flow, velocity correlations, Reynolds stresses, Prandtl's mixing length theory, Karman's velocity defect law, universal velocity distribution, concepts of closure model, eddy viscosity models of turbulence, zero equation, one equation and two-equation models.

Suggested Readings:

Fluid Mechanics,
F. M. White,
McGraw-Hill Higher Education, 8th edition.

Fluid Mechanics,
I. Kohen, P. K. Kundu,
Elsevier, 3rd edition.

Viscous Fluid Flow,
F. M. White,
McGraw-Hill Higher Education, 3rd edition

An Introduction to Fluid Dynamics,
G. K. Batchelor,
Cambridge University Press.

Introduction to Fluid Mechanics and Fluid Machines,
S. K. Som, G. Biswas and S. Chakraborty
Tata-McGraw-Hill, 3rd Edition.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Quantum Mechanics

Course Code: MATH-DSE-301 -07

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO**☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-07

Course Name: Quantum Mechanics

Brief Course Description:

Statistical Learning is a course designed for students who need to carry out statistical analysis, or "learning", from real data. Emphasis will be placed on the development of statistical concepts and statistical computing. The content will be motivated by problem-solving in many diverse areas of application. This course will cover a range of topics in statistical learning including linear and non-linear regression, classification techniques, resampling methods (e.g., the bootstrap), regularization methods, tree based methods and unsupervised learning techniques (e.g. principle components analysis and clustering).

Prerequisite(s) and/or Note(s): Students are assumed to have studied Partial Differential equation, Statistics and Numerical Analysis.

Course Objectives:

Knowledge acquired:

The student has gained knowledge about

(1) The basic non-relativistic quantum mechanics
(2) The time-dependent and time-independent Schrödinger equation for simple potentials like for instance the harmonic oscillator and hydrogen like atoms, as well as the interaction of an electron with the electromagnetic field
(3) The quantum mechanical axioms and the matrix representation of quantum mechanics
(4) The approximate methods for solving the Schrödinger equation (the variational method, perturbation theory, Born approximations)
(5) Spin, angular momentum states, angular momentum addition rules, and identical particles.

Skills gained:

The student is able to

(1) Apply principles of quantum mechanics to calculate observables on known wave functions
(2) Solve time-dependent and time-independent Schrödinger equation for simple potentials
(3) Apply the variational method, time-independent perturbation theory and time-dependent perturbation theory to solve simple problems
(4) Combine spin and angular momentam

Competency developed:

The student has gained

(1) General experience with non-relativistic quantum mechanics that is useful for further studies in theoretical physics, as well as nanotechnology
(2) Knowledge about fundamental quantum mechanical processes in nature
(3) Experience using mathematical tools to construct approximate quantum mechanical models

Course Syllabus:

- Inadequacies of classical mechanics; Planck's quantum hypothesis; Photoelectric effect; Compton experiment; Bohr model of hydrogenic atoms, Wilson-Sommerfeld quantization rule, Correspondence principle, Stern-Gerlach experiment (brief description and conclusion only).
- de Broglie hypothesis; mater waves; uncertainty principle; double-slit experiment; Concept of wave function; Gedanken experiments.
- Time-dependent Schrodinger equation; Statistical interpretation – conservation of probability, equation of continuity, expectation value, Ehrenfest theorem; Formal solution of Schrodinger equation – time-independent Schrodinger equation, stationary state, discrete and continuous spectra, parity.
- Solutions of Schrodinger equation in one-dimension: Infinite potential box; Step potential; Potential barrier; Potential well.
- Classical description; Schrodinger method of solution; Energy levels and wave functions; Planck's law.
- Schrodinger equation for hydrogenic atoms; Solution in spherical polar coordinates; Spherical Harmonics, Energy levels and wave functions; Radial probability density.
- Concept of wave function space and state space; Observables; Postulates of quantum mechanics; Physical interpretations of the postulates – expectation values, Ehrenfest theorem, uncertainty principle.

Suggested Readings:

Quantum Mechanics,
B. H. Bransden, C. J. Joachain,
Prentics Hall, (2005).

Introduction to Quantum Mechanics,
D. J. Griffiths,
Pearson Prentics Hall, Upper Saddle River, NJ, (2005).

Quantum Mechanics,
S. N. Ghoshal,
S Chand & Company Ltd, Kolkata, (2002).

Quantum Mechanics,
L. I. Schiff,
McGraw-Hill, New York, (1968).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Statistical Learning

Course Code: MATH-DSE-301-08

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-08

Course Name: Statistical Learning

Brief Course Description:

Mathematical modeling and simulation are important research and monitoring tools used to understand biological communities and their relationships to the environment. Mathematical models are collections of variables, equations, and starting values that form a cohesive representation of a process or behavior. Because interactions among the members of biological communities and components of the abiotic environment are extremely complex, mathematical models are useful for understanding how ecosystems function and for making predictions about managing ecosystems. There are numerous types of mathematical models used by ecologists and environmental scientists. Some models isolate the key factors that drive elements of a system. Other mathematical models are comprehensive simulations that include as many components and interactions as possible. Mathematical models also cover different spatial and temporal scales: from the smallest tide pool ecosystem to the entire planet; from a single day to millions of years.

Prerequisite(s) and/or Note(s): Students are assumed to have studied Basic knowledge of Statistics.

Course Objectives:

Knowledge acquired:

(1) Understand the basic concepts of Statistics and data analysis

(2) Understand the concepts of regularizations and smoothing

(3) Interpret model assessment and to understand maximum likelihood methods.

(4) Get well versed with unsupervised learning

Skills gained:

(1) Get knowledge on linear regression and supervised learning.

(2) Understand linear methods for regression, classifications, indicator matrix, and separating hyper planes

(3) Describe regularizations, spline smoothening, wavelet smoothing and Kernel smoothers

(4) Analyze model assessment, bootstrap methods and EM algorithm

Competency developed:

(1) Develop skills on practical problem solving in statistics

(2) Get ability to solve problems on Linear methods for regression and classifications

(3) Acquire the knowledge of statistics

Course Syllabus:

- Supervised learning Overview of linear regression (LR), and statistical learning, supervised learning, variable types and simple approaches for predication, statistical models, classes of restricted estimates.

- Linear methods for regression and classifications Linear methods for regression, LR models and least square, subset selection and coefficient shrinkage, linear methods for classifications, indicator matrix, separating hyper planes.
- Regularizations and smoothing Basis expansions and regularizations, piecewise polynomial and splines, filtering and feature extraction, spline smoothening, wavelet smoothing, Kernel smoothers, local regression in *R*p, Local likelihood and other models, radial basis functions and kernels.
- Model assessment and selection Model assessment and bias, model complexity, optimism of training error rate, minimum description length, bootstrap and maximum likelihood methods, the EM algorithm.
- Unsupervised learning Unsupervised learning, association rules, market basket example and analysis, cluster analysis, proximity matrices, algorithms, self-organizing maps, principal components, curves and surfaces, non-negative matrix factorization.

Suggested Readings:

The Elements of Statistical Learning: Data Mining,
J. H. Friedman, R. Tibshirani, T. Hastie,
Inference, and Prediction, Springer, 2nd Ed., (2009).

Fundamentals of Applied statistics,
S. C. Gupta, V. K. Kapoor,
Sultan Chand and sons, (2003).

Probability Statistics and Random processes,
T. Veerarajan,
TMH, First reprint, (2007).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Measurability and Integration in Abstract Spaces

Course Code: MATH-DSE-301-09

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-09

Course Name: Measurability and Integration in Abstract Spaces

Brief Course Description:

Abstract measure spaces, Outer measures, Integration on a measure space, Lebesgue measure, Measurable sets and functions, Lebesgue integration, Some convergence theorems, Lebesgue integral under linear transformation.

Prerequisite(s) and/or Note(s): Extended Real Numbers, Infinite Series, Sigma Algebra, Riemann Integration

Course Objectives:

Knowledge acquired:

(1) Concepts of simple functions.

(2) Integration of functions on arbitrary measure space.

(3) Regular only measure and metric outer measure.

Skills gained:

(1) Generalization of classical Lebesgue integral on real sets.

(2) Integration of bounded functions on sets of finite measure.

Competency developed:

Ability of applying the concepts of integration for the study in subsequent chapters namely, signed and product measure.

Course Syllabus:

- Construction of measure by means of outer measure, regular outer measure and metric outer measure, basic properties, construction of outer measure. Integration on measure spaces, integration of simple functions, integration of bounded functions on sets of finite measure, Lebesgue integral of non-negative functions, monotone convergence theorem, Lebesgue integral of measurable functions, convergence theorems, translation and linear transformation of the Lebesgue integral on $\mathbb{R}$.

Suggested Readings:

Lectures on Real Analysis,
J. Yeh,
World Scientific (2000).

Real analysis, Macmillan Publishing Co.,
H. L. Royden,
Inc. 4th Edition, (1993).

Measure and integration,
S. K. Berberian,
Chelsea Publishing Company, NY, (1965).

Measure Theory and integration,
G. D. Barra,
Wiley Eastern Ltd, (1981).

The Elements of Integration,
R. G. Bartle,
John Wiley & Sons, Inc. New York, (1966).

An Introduction to Measure and Integration,
I. K. Rana,
Narosa Publishing House, Delhi.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Algebraic Topology

Course Code: MATH-DSE-301-10

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? **YES** ☑ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? **YES** ☑ NO ☐

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☑

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

Computation of cohomology groups is a very good addition to this syllabus. An extra weightage has been given to the application part.

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-10

Course Name: Algebraic Topology

Brief Course Description:

The aim of the course is to show how basic geometric structures may be studied by transforming them into algebraic questions. Studying geometric objects by associating algebraic invariants to them is a powerful idea which influenced many areas of mathematics. The goal of the course is to introduce the most important examples of such invariants such as homology and cohomology groups, and to calculate them for fundamental examples and constructions of topological spaces. Algebraic topology as a preparatory course on application of topology.

Prerequisite(s) and/or Note(s): Students are assumed to have studied Graduate level mathematics, Point set topology.

Course Objectives:

Knowledge acquired:

The student has knowledge of fundamental concepts and methods in algebraic topology, in particular homology.

Skills gained:

The student is able to apply his or her knowledge of algebraic topology to formulate and solve problems of a geometrical and topological nature in mathematics.

Competency developed:

Students will be able to identify the problems where topology may be the best suitable alternative to solve them.

Course Syllabus:

- Homotopy of maps, multiplication of paths, Fundamental Groups, induced homomorphisms, Fundamental groups of Circle,Sphere and some surfaces. Covering spaces, lifting theorems, the universal covering space, Seifert-van Kampen theorem, applications. Geometrical construction of group structure on circle (in fact on any conic), Separation Theorem in the plane, Classification of surfaces.
- Simplicial complexes, chain complexes, definitions of the simplicial homology groups, properties of homology groups, cohomology groups and applications.

Suggested Readings:

Basic Topology,
M. A. Armstrong
Springer (India).

Algebraic Topology,
A. Hatcher
Cambridge University Press.

First Course in Algebraic Topology,
C. A. Kosniowski
Cambridge Univ. Press.

Basic Concepts of Algebraic Topology,
F. H. Croom
Springer-Verlag.

Algebraic Topology-A Primer,
S. Deo
Hindustan Book Agency.

Topology,
J. R. Munkres
PHI.

Basic Algebraic Topology,
A. R. Shastri
CRC Press Book.

Department Name:	Mathematics
Program Name:	PG in Mathematics
Program Code:	
Semester:	Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐
Course Name:	Elementary Number Theory
Course Code:	MATH-DSE-301-11
Course Credit:	2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-11

Course Name: Elementary Number Theory

Brief Course Description:

Elementary Number Theory deals with the basics of number theory including linear congruence, arithmetical functions and their Dirichlet product, quadratic residues, algebraic number fields, introduction to Riemann Zeta function and infinitude of primes, quadratic fields, cyclotomic fields and related topics.

Prerequisite(s): Students are assumed to have studied Undergraduate level mathematics.

Course Objectives:

Knowledge acquired:

(1) Congruence and Chinese Remainder Theorem.

(2) Arithmetical functions

(3) Quadratic reciprocity Law.

(4) Algebraic number field.

Skills gained:

(1) Use of congruence as a tool to reduce a hard labour of work in some calculations.

(2) Finding primitive roots.

(3) Establishing existing identities using Mobius inversion formula.

(4) Finding quadratic residues.

(5) Solving problems related to quadratic and cyclotomic fields.

Competency developed:

Useful tools in various areas of number theory, viz. analytic and algebraic number theory, cryptography, modular forms etc.

Course Syllabus:

- Linear congruence, Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.
- Arithmetic functions, multiplicative functions, Mobius inversion formula, Euler's theorem.
- Structure of units modulo n, primitive roots, quadratic residues, law of quadratic reciprocity.
- Representation of integers as sum of squares, Fermat's two square theorem, Lagrange's four-square theorem.
- Dirichlet product of Arithmetic functions, Characters of a finite abelian group. Introduction to Riemann Zeta function and infinitude of primes, infinitude of primes in specific arithmetic progressions, Dirichlet's theorem (without proof).
- Algebraic number fields and the ring of integers. Trace and norm of an element in a field, units and primes, factorization, quadratic and cyclotomic fields.

Suggested Readings:

Elementary Number Theory,
D. M. Burton
University of New Hampshire.

Introduction to Analytic number theory,
T. M. Apostol
UTM, Springer, (1976).

An Introduction to the Theory of Numbers,
G. H. Hardy, E.M. Wright
6th ed., Oxford University Press, (2008).

Number Fields,
D. A. Marcus
Universitext, Springer-Verlag, (1977).

Algebraic Number Fields,
G. J. Janusz
Graduate Studies in Mathematics 7, American Mathematical Society, (1996).

Algebraic Number Theory,
S. Lang
Graduate Texts in Mathematics 110, Springer-Verlag, (1994).

Algebraic number theory,
J. W. S. Cassel, A. Frohlich
Cambridge.

Introduction to Analytic Number Theory,
K. Chandrasekharan
Springer-Verlag, (1968).

Analytic Number Theory,
H. Iwaniec, E. Kowalski
American Mathematical Society Colloquium Publications 53, American Mathematical Society, (2004).

Algebraic Number Theory,
R. A. Mollin
Chapman & Hall/CRC.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Advanced Complex Analysis- I

Course Code: MATH-DSE-301-12

Course Credit: 2

Marks Allotted: Theoretical/Practica 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO**☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-12

Course Name: Advanced Complex Analysis- I

Brief Course Description:

This course deals with Convex function and Hadamard Three-Circle Theorem, Convergence and Comnpactness in the space of analytic function and their application, Riemann Mapping theorem, Theory of Entire functions, Weierstrass Factorization Theorem and lastly the Theorems of Boral and Picard.

Prerequisite(s) and/or Note(s):

(1) Basic Complex Number and Complex Analysis
(2) Real Analysis and Calculus

Course Objectives:

To present a systematic introduction on the detailed study on complex analysis with the presentation of the detailed theory of entire functions, and their important properties.

Knowledge acquired:

On completion of the course, the student would gain knowledge on

(1) The deeper aspects of complex analysis.
(2) The study of entire functions with its growth and distribution of their zeros.
(3) Weierstrass factor theorem.
(4) Concepts of canonical product, Hadamard's factorization theorem and Picard's theorems.
(5) Further applications in various branches of mathematical sciences.

Skills gained:

(1) Ability of constructing maximum modulus function M(r)
(2) Analysis on the space of analytic functions.
(3) Ability to solve problems in entire function theory.
(4) Concrete idea about range of entire functions.

Competency developed:

(1) Solving problems using maximum modulus
(2) Ability of identifying compact subsets in the space of analytic functions.
(3) Factorizing entire functions as infinite product.
(4) Applications to problems from real analysis

Course Syllabus:

- The functions M(r) and A(r). Theorem of Borel and Caratheodary, Convex function and Hadamard three-circle theorem.
- Convergence and Compactness in the space of analytic function, Riemann Mapping theorem.
- Entire functions, growth of an entire function, order and type and their representations in terms of the Taylors coefficients, distribution of zeros, Picards's first theorem.
- Weierstrass factorization theorem, the exponent of convergence of zeros.
- Canonical product, Hadamard's factorization theorem, Borel's theorems, Picard's second theorem.

Suggested Readings:

Theory of Functions of a Complex Variables,
A. I. Markusevich
Vol. I & II, Printice-Hall, (1965).

Introduction to the theory of entire function,
A. S. B. Holland
Academic Press New York and London, (1973).

Functions of One Complex Variable,
J. B. Conway
Narosa Publishing House, New Delhi, 2nd Edn, (1997).

Complex Analysis,
L. V. Ahlfors
McGraw-Hill, 3rdEdn. (1979).

Entire Functions,
R. P. Boas
Academic Press, (1954).

Theory of Analytic Functions,
H. Cartan
Dover Publication, (1995).

Complex Analysis, Springer,
T. W. Gamelin
New York, (2001).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Advanced Functional Analysis

Course Code: MATH-DSE-301-13

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

- Core ☐
- Department Specific Elective ☑
- Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-13

Course Name: Advanced Functional Analysis

Brief Course Description:

Approximation in Norm Spaces, Strict Convexity, Uniform Approximation, Chebyshev Polynomial, Approximation in Hilbert Space, Spectral Theory in Finite Dimensional Normed Spaces, Spectral Properties of Bounded Linear Operators, Properties of Resolvent and Spectrum, Banach Algebras, Compact Linear Operators in Normed Space and Their Spectral Properties, Spectral Properties of Bounded Self Adjoint Linear Operators and Their Spectral Family, Positive and Projection Operators, Unbounded linear operators in Hilbert space. Hellinger-Toeplitz theorem of boundedness.

Prerequisite(s) and/or Note(s): Students are assumed to have studied Real Analysis, Linear Algebra, Basic Functional Analysis.

Course Objectives:

Knowledge acquired:

(1) Strict convexity.

(2) Operator theory.

(3) Spectral Properties of Bounded Self Adjoint Linear Operators.

(4) Unbounded linear operators in Hilbert space.

Skills gained:

(1) Approximation in Norm Spaces and Hilbert spaces.

(2) Properties of Resolvent and Spectrum of operators.

(3) Analyzing the boundedness of some operator through Hellinger-Toeplitz theorem.

Competency developed:

(1) Explain the fundamental concepts of functional analysis and their role in modern mathematics and applied contexts.

(2) Demonstrate accurate and efficient use of functional analysis techniques.

(3) Apply problem-solving using functional analysis techniques applied to diverse situations in physics, engineering and other mathematical contexts.

Course Syllabus:

- Best approximation. Existence theorem of best approximations. Strict convexity. Hilbert space is strictly convex. The space C[a,b] with sup-norm is not a strictly convex. Uniqueness theorem of best approximation. Uniform approximation. Extremal point. Haar condition. Haar uniqueness theorem. Chebyshev polynomials. Approximation in Hilbert space. Spline approximation.
- Spectral theory in finite dimensional normed spaces. Eigenvalue of an operator. Regular value of an operator. Resolvent set of an operator. Spectrum of an operator. Spectral properties of bounded linear operators. Spectral radius. Spectral mapping theorem for polynomials. Banach Algebra. Compact linear operators on normed spaces and their spectrum. Spectral properties of compact linear operators on normed spaces. Spectral

theory of bounded self-adjoint linear operators. Spectral properties of bounded self-adjoint linear operators. Spectral family of a bounded self-adjoint linear operator. Spectral representation of bounded self-adjoint linear operators. Extension of the spectral theorem to continuous functions. Unbounded linear operators in Hilbert space. Hellinger-Toeplitz theorem of boundedness. Spectral properties of self-adjoint linear operator.

Suggested Readings:

Introductory Functional Analysis with Applications,
K. Kreyszig,
John Wiley &Sons New York, 1978.

Elements of Functional Analysis,
B. K. Lahiri,
The World Press Pvt. Ltd. Calcutta, 1994.

Introduction to Topology and Modern Analysis,
G. F. Simmons,
McGraw-Hill Co. New York, 1963.

A course in functional analysis,
J. B. Conway,
Springer-Verlag, New York 1990

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Theory of Approximation

Course Code: MATH-DSE-301-14

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-14

Course Name: Theory of Approximation

Brief Course Description:

Approximation in Normed Spaces, The Lp-norms, Convexity conditions, Conditions for the uniqueness for the best approximation, The continuity of best approximation operators, The Weierstrass theorem and Bernstein polynomial approximation, Korovin theorem, Jacson's theorems and their Converse Theorems. Approximation by means of Fourier Series.

<u>Prerequisite(s) and/or Note(s)</u>: Students are assumed to have studied Functional Analysis, Measure Theory and Complex Analysis.

Course Objectives:

<u>Knowledge acquired:</u>

(1) Definition Concept of best approximation in a normed linear space.
(2) Convexity-uniform convexity, strict convexity and their relations.
(3) Weierstrass theorem, Korovin theorem.
(4) Bernstein polynomials.
(5) Bernstein's inequality.
(6) Jacson's theorems.
(7) Haar uniqueness theorem.
(8) Simultaneous approximation.
(9) Lp-approximation.

<u>Skills gained:</u>

(1) Hilbert space is strictly convex and the space C[a,b] with z-norm is not a strictly convex.
(2) Extremal point.
(3) Chebyshev polynomials.
(4) Lipschitz class.
(5) Approximation by means of Fourier Series.

<u>Competency developed:</u>

Apply uniform convexity and strict convexity notions.

Course Syllabus:

- Concept of Best Approximation in a Normed Linear Space, Existence of the Best Approximation, Uniqueness Problem, Convexity-Uniform Convexity, Strict Convexity and their relations.
- Continuity of the best Approximation Operator. The Weierstrass Theorem, Bernstein Polynomials, Korovin Theorem, Algebraic and Trigonometric polynomials of the best Approximation. Lipschitz class, Modulus of Continuity, Integral Modulus of Continuity and their properties.

- Bernstein's Inequality. Jacson's Theorems and their Converse Theorems. Approximation by means of Fourier Series.
- Positive Linear Operators, Monotone Operators, Simultaneous Approximation, Lp approximation. Approximation of analytic Functions.

Suggested Readings:

Fundamentals of Approximation Theory,
H. M. Mhaskar, D. V. Pai,
Narosa Publishing House.

Theory of Approximation of Functions of a Real Variable,
F. Timan,
Dover Publication Inc.

Introduction to Approximation Theory,
E. W. Cheney,
AMS Chelsea Publishing Co.

Bernstein Polynomials,
G. G. Lorentz,
Chelsea Publishing Co.

Constructive Function Theory Volume-I,
P. Natanson,
Fredrick Ungar Publishing Co.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Fuzzy Mathematics

Course Code: MATH-DSE-301-15

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-15

Course Name: Fuzzy Mathematics

Brief Course Description:

Uncertainty, Fuzzy sets, Membership functions, Operations on fuzzy sets, Properties of fuzzy sets, Fuzzy relations, Min-Max composition, Fuzzification, Defuzzification, Algebraic operations with fuzzy numbers, Fuzzy logic.

Prerequisite(s) and/or Note(s): Students are assumed to have studied Graduate level mathematics, Set Theory.

Course Objectives:

Knowledge acquired:

(1) Concept of uncertainty and fuzziness.

(2) Concept of fuzzy set and their types.

(3) Different properties of fuzzy sets.

(4) Concept of fuzzy relation and fuzzy equivalence relations.

(5) Membership functions and their properties.

(6) Concept of fuzzy integration and fuzzy differentiation etc.

(7) Concept of fuzzy logic.

Skills gained:

(1) Performing operations on fuzzy sets.

(2) Formulate different membership functions.

(3) Ability to create new fuzzy relation using fuzzy composition.

(4) Ability to fuzzify and defuzzify to crisp sets.

(5) Ability to calculate the value of fuzzy integration of a fuzzy function.

(6) Identify different fuzzy logical statements.

Competency developed:

Helpful tool for any advanced higher Mathematics, e.g. Algebra, Topology, Graph theory, Optimization etc.

Course Syllabus:

- Historical Perspective, Importance and limitations of fuzzy systems, Uncertainty, Fuzzy sets and membership functions, Type of fuzzy sets, Operations on fuzzy sets, Properties of fuzzy sets, Fuzzy relations and its properties, Compositions of fuzzy relations, Fuzzy equivalence relation, Min-Max composition, Value assignments, Properties of membership functions, Various forms, Fuzzification, Defuzzification to crisp sets, Algebraic operations with fuzzy numbers, Integration of fuzzy functions, integration of a fuzzy function over a crisp set, Fuzzy differentiation, Fuzzy logic and approximate reasoning, Fuzzy logic rule base, Fuzzy IF-THEN, Fuzzy logic rule base, Interpretation and evaluation of Fuzzy IF-THEN Rules, Fuzzy languages.

Suggested Readings:

Fuzzy Set Theory and Applications
H. J. Zimmerman,
Springer Science Business Media, LLC.

Fuzzy Logic with Engineering Applications
Timothy J. Ross,
John Wiley & Sons, Ltd., Publication.

Fuzzy Sets and Fuzzy Logic Theory and Applications
George J. Klir and Bo Yuan,
Prentice Hall P T R Upper Saddle River, New Jersey 07458.

A First Course in Fuzzy Logic
Hung T. Nguyen, Carol L. Walker and Elbert A. Walker,
Chapman and Hall/CRC.

First Course on Fuzzy Theory and Applications
Kwang H. Lee,
Springer International Edition, 2005.

An Introduction to Fuzzy Set Theory and Fuzzy Logic
Chander Mohan,
Anshan Publishers.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Algebraic Geometry

Course Code: MATH-DSE-301-16

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-16

Course Name: Algebraic Geometry

Brief Course Description:

Categories and functors, Limits and colimits, Spectral sequences, Definition of sheaf and presheaf, Sheaves of abelian groups, The inverse image sheaf, Toward schemes, Visualizing schemes I: generic points, Visualizing schemes II: nilpotents, Definition of schemes, Reducedness and integrality, Normality and factoriality, Morphisms of schemes, Images of morphisms, Representable functors and group schemes, Pulling back families and fibers of morphisms, Normalization, Separated and proper morphisms, Dimension and codimension, Noether normalization, Regularity and smoothness, The Zariskitangent space, Valuative criteria for separatedness and properness.

Prerequisite(s) and/or Note(s): Students are assumed to have studied Graduate level mathematics.

Course Objectives:

Knowledge acquired:

(1) Concept of category, Morphisms

(2) Idea of Limit, colimit

(3) Functor, Representable functor

(4) Concept of Spectral sequences, sheaf and presheaf

(5) Concept of Dimension and codimension, Noether normalization

Skills gained:

(1) Construction of different functors

(2) Ability to study different categories

(3) Calculating limit, colimits etc.

(4) Ability to study different schemes

Competency developed:

(1) Study the high-level abstractions such as sets, rings, and groups

(2) Philosophical investigations of concepts such as space, system and even truth. Study of logical systems

Course Syllabus:

- Some category theory, Motivation, Categories and functors, Universal properties determine an object up to unique isomorphism, Limits and colimits, Adjoints, An introduction to abelian categories, Spectral sequences, Sheaves. Motivating example: The sheafof differentiable functions. Definition of sheaf and presheaf, Morphisms of presheaves and sheaves, Properties determined at the level of stalks, and sheafification, Sheaves of abelian groups, and OX-modules, form abelian categories, the inverse image sheaf, Recovering sheaves from a “sheaf on a base”.
- Toward affine schemes: the underlying set, and topological space, Toward schemes, The underlying set of affine schemes, Visualizing schemes I: generic points, The underlying topological space of an affine scheme, A base of the Zariski topology on Spec A: Distinguished open sets, Topological (and Noetherian) properties, The function I(·), taking

subsets of Spec A to ideals of A, The structure sheaf, and the definition of schemes in general, The structure sheaf of an affine scheme, Visualizing schemes II: nilpotents, Definition of schemes , Three examples, Projective schemes, and the Proj construction, Some properties of schemes, Topological properties, Reducedness and integrality, Properties of schemes that can be checked "affine-locally", Normality and factoriality, Where functions are supported: Associated points of schemes.

- Morphisms of schemes, Introduction, Morphisms of ringed spaces, From locally ringed spaces to morphisms of schemes, Maps of graded rings and maps of projective schemes, Rational maps from reduced schemes, Representable functors and group schemes, The Grassmannian (initial construction), Useful classes of morphisms of schemes, An example of a reasonable class of morphisms: Open embeddings, Algebraic interlude: Lying Over and Nakayama, A gazillion finiteness conditions on morphisms, Images of morphisms: Chevalley's theorem and elimination theory, Closed embeddings and related notions, Closed embeddings and closed subschemes, More projective geometry, Smallest closed subschemes such that ... ,Effective Cartier divisors, regular sequences and regular embeddings, Fibered products of schemes, and base change, They exist, Computing fibered products in practice, Interpretations: Pulling back families, and fibers of morphisms, Properties preserved by base change, Properties not preserved by base change, and how to fix them, Products of projective schemes: The Segre embedding, Normalization, Separated and proper morphisms, and (finally!) varieties, Separated morphisms (and quasi separatedness done properly), Rational maps to separated schemes, Proper morphisms.
- Dimension, Dimension and codimension , Dimension, transcendence degree, and Noether normalization, Codimension one miracles: Krull's and Hartogs's Theorems, Dimensions of fibers of morphisms of varieties, Proof of Krull's Principal Ideal and Height Theorems, Regularity and smoothness, The Zariskitangent space, Regularity, and smoothness over a field, Examples, Bertini's Theorem, Discrete valuation rings: Dimension, Noetherian regular local rings, Smooth (and etale) morphisms (first definition), Valuative criteria for separatedness and properness, More sophisticated facts about regular, local rings, Filtered rings and modules, and the Artin-Rees Lemma.

Suggested Readings:

Introduction to Commutative Algebra,
M. F. Atiyah, I. G. MacDonald,
Addison-Wesley, (1969).

Commutative Algebra,
J. S. Milne,
Cambridge University Press, (2017).

Fields and Galois Theory,
J. S, Milne,
Taiaroa Publishing, (2017).

Algebraic Geometry,
R. Hartshorne,
Springer, (1977).

Basic Algebraic Geometry,
R. Shafarevich
Springer, (1994***)***.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III** ☑ Semester IV ☐

Course Name: Category Theory

Course Code: MATH-DSE-301-17

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-17

Course Name: Category Theory

Brief Course Description:

Category, Opposite category, Product category, The duality principle, Functors, Hom functors, Representable functors, Product of functors, Natural transformations, Functor categories, Universal and adjoint functors.

Prerequisite(s): Students are assumed to have studied Graduate level mathematics.

Course Objectives:

Knowledge acquired:

(1) Concept of category, Morphisms
(2) Functor, forgetful functor, faithful functor
(3) Product category
(4) Natural transformation
(5) Representable functor, embedding
(6) Yoneda's lemma and its applications
(7) Adjoint functor. Initial object, terminal object
(8) Limit, colimit, pull back diagram, and push out diagram

Skills gained:

(1) Construction of different functors
(2) Ability to study different categories
(3) Calculating natural transformations, limit, colimits etc

Competency developed:

(1) Study the high-level abstractions such as sets, rings, and groups
(2) Philosophical investigations of concepts such as space, system and even truth. Study of logical systems

Course Syllabus:

- Category, Diagrams, Monic, Epic, Initial & terminal objects, Sections & retractions, large, small & locally small category, Subcategory, Opposite category, Product category.
- The duality principle, Product & coproduct of objects, Pullback & pushout, Equalizers & coequalizers, Limit & colimit.
- Functors (covariant & contravariant), Full, faithful, equivalence & isomorphism functors, Forgetful functors, Hom functors, Representable functors, Product of functors.
- Natural transformations, vertical & horizontal compositions, Functor categories, Category of categories, Exponentials of categories, Yoneda's lemma and its applications, Universal and adjoint functors, Equivalence of categories.

Suggested Readings:

Category Theory,
S. Awodey,
Oxford University Press, (2010).

Categories for the working Mathematician,
S. M. Lane,
Springer, (2013).

An Introduction to Category Theory,
H. Simmons,
Cambridge University Press, (2011).

Basic Category Theory,
T. Leinster,
Cambridge University Press, (2014).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: General Theory of Integration

Course Code: MATH-DSE-301-18

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-301-18

Course Name: General Theory of Integration

Brief Course Description:

Tagged Gauge Partitions, Cousin's Theorem, Henstock–Kurzweil Integral, Fundamental Theorem, Saks-Henstock Lemma, Squeez Theorem, Vitali-Covering Theorem, Differentiation Theorem, Characterization Theorem.

Prerequisite(s): Students are assumed to have studied Real Analysis, Calculus, Measure Theory.

Course Objectives:

Knowledge acquired:

(1) Concepts of Tagged Gauge Partition

(2) Intrinsic power of tagged partition

(3) Henstock-Kurzweil Integral

(4) Important properties including Saks-Henstock Lemma and Vitali covering Theorem

Skills gained:

(1) Understanding the use of Tagged partition and its applications in continuity

(2) Using Right-Left procedure appropriately

(3) Understanding basic properties

Competency developed:

(1) Viewing Heustock integral as the highest possible generalized integral on $\mathbb{R}$

(2) Realizing that HK-integration corrects the defects of Classical Riemann Theory and both simplifies and extends Lebesgue Theory

Course Syllabus:

- Tagged Gauge Partitions. Definitions, Cousins Theorem, Right-left Procedure, Straddle Lemma, Application in continuity, Intrinsic Power. Henstock–Kurzweil Integral, Definition and basic properties.
- Fundamental Theorem, Saks-Henstock Lemma, Inclusion of the Lebesgue integral. Squeez Theorem, Vitali- Covering Theorem, Differentiation Theorem, Characterization Theorem.

Suggested Readings:

A Modern Theory of Integration,
R. G. Bartle,
AMS.

Theories of Integration,
D. S. Kurtz, C. W. Swartz,
World Scientific.

Lectures on Henstock Integration,
L. P. Yee, Lanzhou,
World Scientific.

The Riemann, Lebesgue and General Riemann Integrals
A. G. Das,
Narosa.

The general Theory of integration,
R. Henstock,
Clarendon Press.

Department Name:	Mathematics
Program Name:	PG in Mathematics
Program Code:	

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name:	Mathematical Spaces and Curves
Course Code:	MATH-GE-301-01
Course Credit:	4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation 20

Course Type (tick the correct alternatives):

- Core ☐
- Department Specific Elective ☐
- **Generic Elective** ☑

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-301-01

Course Name: Mathematical Spaces and Curves

Brief Course Description:

Mathematical Spaces and Curves deals with the study of different types of spaces and curves encountered while studying various topics in mathematics. In particular, the course will cover metric space, space of continuous functions, normed space, measure space, topological space and related topics. It will also cover some basic ideas of curves.

Prerequisite(s): Students are assumed to have studied Undergraduate level Mathematics

Course Objectives:

Knowledge acquired:

(1) Metric Space, Normed Space, Measure Space, Topological Space, etc.
(2) Different type of curves and their curvature.

Skills gained:

Solving problems related to mathematical spaces and curves using its properties

Competency developed:

Analyzing and solving problems

Course Syllabus:

- Metric space: Definition and Examples, complete space, compact sets, completion of a metric space.
- Space of continuous functions: modes of continuity, modes of convergence. Space of bounded functions, space of bounded and continuous functions.
- Normed spaces, Equivalent norms, Banach space. Inner product space, Cauchy-Schwarz Inequality, Pythagorean Theorem, Statement of Parseval's Theorem.
- Measure space: Definition and Examples.
- Topological space: Definition and Examples, basis, introduction to T_0, T_1 and T_2 spaces.
- Curve: Definition and examples, level curve, slope of a curve, arc-length, parametrization of curves, tangent and normal.
- Reparametrization of curves, regular point, regular curve, closed curve and its period.
- Curvature, planes curves and space curves, Serret-Frenet equations.
- Simple closed curves: Definition, examples and its total signed curvature.

Suggested Readings:

An introduction to Real Analysis,
T. L. Lindstrom, Spaces
American Mathematical Society, Indian Edition, 2019.

Topology of Metric Spaces, 2nd Ed.,
S. Kumaresan
Narosa Publishing House, 2011.

Introduction to Topology and Modern Analysis,
G. F. Simmons
McGraw-Hill, 2004.

Introductory Functional Analysis with Applications,
E. Kreyszig
Wiley Student Edition.

Fundamentals of Real Analysis,
S. K. Berberian
Springer.

Measure Theory and Integration,
G. De Barra
New Age International Publication.

Real Analysis,
H. L. Royden
Prentice-Hall of India Pvt. Limited, (1988).

Principles of Mathematical Analysis,
W. Rudin
McGraw-Hill, (2013).

Topolpgy-2nd Edition
J. R. Munkres
Pearson**.**

Elementary Differential Geometry,
Andrew Pressley,
Springer

Thomas' Calculus,
Maurice D. Weir & Joel Hass
Pearson

Differential Geometry of Curves and Surfaces,
Kristopher Tapp,
Springer.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV☑**

Course Name: Statistical foundation for Data Science

Course Code: MATH-GE-301-02

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☑

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-301-02

Course Name: Statistical foundation for Data Science

Brief Course Description:

Random experiment, Random variable, Probability mass function (p.m.f) and probability density function (p.d.f), Mathematical expectation, Variance and covariance, Moment generating function (m.g.f), Discrete and Continuous probability distributions. Population, Sample, Measures of central tendency (Mean, Median, Mode), Measures of dispersion (Standard deviation, Mean deviation). Sampling, Method of sampling, Sampling distribution, Statistical inference and Statistical Hypothesis.

Prerequisite(s) and/or Note(s): The students are assumed to have studied basic Algebra, Differential and Integral calculus in UG courses.

Course Objectives:

Knowledge acquired:

Upon completion of this course, student will be able to gain the following knowledge of:

(1) the basic definition and different approaches to Probability, Various type of Probability distributions like Bernoulli distribution, Binomial distribution, Poisson distribution, Geometric distribution, Hypergeometric distribution, Normal distribution, Rectangular distribution, Gamma distribution, Cauchy distribution etc.

(2) Concept of Population, meaning and utility of sampling in Statistics, various type of sampling, various measures of central tendency and measures of dispersions, Sampling distributions, Theory of estimation, Various characteristics of estimators, Statistical inference and the concept of testing of Hypothesis

Skills gained:

(1) to distinguish between discrete and continuous random variables, distributions

(2) to apply probability distribution to a variety of problems in a various diversified fields

(3) to compute, interpret and distinguish correlation coefficient, using regression analysis to develop equations for estimating the relationship between two variables

(4) to use regression analysis for estimation and prediction purposes

(5) to develop a framework for testing of hypothesis

(6) to use chi-square distribution to conduct the test of goodness of fit and to make inference about population variance

Competency developed:

(1) After completion of the course, students should be able to gain the knowledge of statistics and then to apply it in real life situation

(2) Students will also be able to apply this knowledge in the field of Economics, Bio-Science, Medical Science, Epidemic study etc.

Course Syllabus:

- Random experiment, Outcome, Event, Addition and multiplication of probability, Boole's inequality, Conditional probability, Independent event, Baye's theorem. Random variable, Probability mass function (p.m.f) and probability density function (p.d.f),
- Mathematical expectation, Variance and covariance, Moment generating function (m.g.f), Characteristics function, Tchebycheff's inequality, Convergence in probability, Bernoulli's theorem, Law of large numbers.
- Discrete Probability distribution: Bernoulli distribution, Binomial distribution, Poisson distribution, Geometric distribution, Hypergeometric distribution.
- Continuous distribution: Normal distribution, Rectangular distribution, Exponential distribution, Gamma distribution, Cauchy distribution, Central limit theorem.
- Statistics: Measures of central tendency (Mean, Median, Mode), Measures of dispersion (Standard deviation, Mean deviation), Measures of skewness and kurtosis, Moments, Correlation and regression.
- Sampling theory**:** Meaning and objects of sampling, Method of sampling, Types of sampling, Statistic and parameter, Random sampling, Standard error.
- Sampling distribution: Population, Sample, Sampling distribution of sample mean and sample variance, Chi-square ($\chi 2$) distribution, Student's 't' distribution, F-distribution, Fisher's z-distribution.
- Statistical inference: Theory of estimation—Point estimation, Interval estimation, Concepts of bias and standard error of estimator, Unbiasedness, Consistency, Efficiency and sufficiency, Maximum likelihood estimation, Moments and least square, Confidence interval, Confidence limit, Minimum Variance Unbiased (MVU) estimators, Cramer-Rao inequality.
- Statistical Hypothesis: Null hypothesis, Alternative hypothesis, Critical region, Type-I and Type-II errors, Level of significance, Neyman-Pearson Lemma.

Suggested Readings:

Fundamentals of Mathematical Statistics,
S. C. Gupta and V. K. Kapoor,
Sultan Chand & Sons (12th Edition), 2020.

A first course in Probability and Statistics,
B. L. S. Prakasa Rao,
World Scientific/Cambridge University Press India, 2009.

Introduction to Mathematical Statistics,
R. V. Hogg, J. W. McKean and A. Craig,
Pearson Education India (6th Ed.), 2006.

Groundwork of Mathematical Probability and Statistics,
A. Gupta,
Academic Publishers (7th Edition,), 2015.

Fundamentals of Statistics,
A. M. Gun, M. K. Gupta, B. Dasgupta,
World Press, India, 2016.

Statistical Inference,
V. K. Rohatgi,
Wiley, 1984

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ **Semester III ☑** Semester IV ☐

Course Name: Mathematical Modelling and Simulations in MATLAB and MATHEMATICA

Course Code: MATH-GE-301-03

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☑

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-301-03

Course Name: Mathematical Modelling and Simulations in MATLAB and MATHEMATICA

Brief Course Description:

Mathematical modelling and simulation are important research and monitoring tools used to understand biological communities and their relationships to the environment. Mathematical models are collections of variables, equations, and starting values that form a cohesive representation of a process or behaviour. Because interactions among the members of biological communities and components of the abiotic environment are extremely complex, mathematical models are useful for understanding how ecosystems function and for making predictions about managing ecosystems. There are numerous types of mathematical models used by ecologists and environmental scientists. Some models isolate the key factors that drive elements of a system. Other mathematical models are comprehensive simulations that include as many components and interactions as possible. Mathematical models also cover different spatial and temporal scales: from the smallest tide pool ecosystem to the entire planet from a single day to millions of years.

Making calculations is at the heart of every science. In this course, we will learn the programming in MATLAB and MATHEMATICA. We write programs to implement mathematical concepts that frequently appear in science and engineering. Through programming, we will gain better understanding of some mathematical ideas prevalent in all sciences and how related calculations are done and the reason they work. MATLAB and MATHEMATICA are particularly popular among engineers but they are similar in its principles to other scientific programming software, such as R, commonly used by statisticians, biologists and other scientists.

<u>Prerequisite(s) and/or Note(s)</u>: Students are assumed to have studied Calculus, Differential Equation.

Course Objectives:

<u>Knowledge acquired</u>**:**

(1) Understand the linear models

(2) Evaluate and learn nonlinear models

(3) Emphasize the significance of compartmental models

(4) Gain comprehensive knowledge and sound understanding of phase-plane analysis and linear optimization

(5) Acquire knowledge on nonlinear models

(6) Solve systems of linear equations using MATLAB/MATHEMATICA

(7) Numerically solve simple differential equations

(8) Find optimum solutions to numerical problems

<u>Skills gained</u>:

(1) Recognize the nonlinear optimization methods

(2) Develop skills on practical, analytical problem solving in some parts of mathematical modelling

(3) Apply the knowledge about nonlinear optimization

(4) Learn and apply the knowledge level to Modelling aspects

(5) Students will be able to write basic programming for numerical analysis, matrix manipulation, 2D and 3D plotting using MATLAB.

(6) Students will be able to write and handle loops, functions, array, matrix operations, method of solving differential and difference equations, data visualization using MATHEMATICA. They will also be able to write basic programs using the aforesaid tools in the MATHEMATICA environment.

Competency developed:

(1) Understand and solve problems on linear models

(2) Correlate the acquired knowledge and use compartmental models

(3) Familiarize themselves with phase-plane analysis and linear optimization

(4) Acquire the knowledge and developing Mathematical Models

(5) Students will gain the confidence to write a program in MATHEMATICA or MATLAB. Then can verify solutions of any system of linear algebraic equations

(6) They will be able to compare the accuracy of different methods

Course Syllabus:

- Overview of mathematical modelling, types of mathematical models and methods to solve the same; Discrete-time linear models: Fibonacci rabbit model, cell-growth model, prey-predator model; Analytical solution methods and stability analysis of the system of linear difference equations; Graphical solution – cobweb diagrams. Leslie Model; Jury's stability test; Numerical methods to find eigenvalues – power method and LR method.
- Different cell division models, prey-predator model; Stability of non-linear discrete-time models; Logistic difference equation; Bifurcation diagrams.
- Limitations & advantage of the discrete-time model, the need for continuous-time models; Ordinary differential equation (ODE) – order, degree, solution, and geometrical significance; Solution of first-order first degree ODE – method of separation of variables, homogeneous equation, Bernoulli equation; Continuous-time models – a model for the growth of microorganisms, chemostat; Stability and linearization methods for system of ODE.
- Allee effect; Qualitative solution of differential equations using phase diagrams; Continuous-time models–Lotka Volterra competition model, prey-predator models.
- Simulation and Monte Carlo integration, Computers as inference machines, Issues in simulation for standard univariate and multivariate distributions, a congruential method for uniform generators, transforming uniforms, and inverse transform method, convolution method, and acceptance-rejection method.
- MATLAB/MATHEMATICA/MAPLE basics: Basic computer programming, variables and constants, operators and simple calculations, formulas and functions, toolboxes, matrices and vectors, vectors and matrices, matrix operations and functions, exercises.
- Algorithms and structures, scripts and functions (m/mb/mw-files), simple sequential algorithms, control structures, reading and writing data, file handling, personalized functions, toolbox structure, graphics, exercises.
- Simulation of systems of ordinary differential equations, simulation of partial differential equations: Wave equations, solution of nonlinear equations: Boundary value problems, Poisson and Laplace equations, solutions of two coupled (algebraic, trigonometric) nonlinear equations, roots of a polynomial, etc., and exercises.

Suggested Readings:

Mathematical Modelling,
J. N. Kapur,

Wiley Eastern Ltd., (1998).

Mathematical modeling and simulation: Introduction for scientists and engineers,
K. Velten,
John Wiley & Sons. (2009).

Mathematical Modelling: A Graduate Textbook,
J. D. Majid and S. M. Moghadas,
John Wiley & Sons. (2018).

Mathematical modeling: models, analysis and applications,
S. Banerjee,
Chapman and Hall/CRC, (2021).

Modelling mathematical methods and scientific computation,
N. Bellomo, and L. Preziosi,
CRC press, (1994).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Dissertation

Course Code: MATH-CC-401

Course Credit: 2

Marks Allotted: Theoretical/Practical: 0 Continuing Evaluation: 50

Course Type (tick the correct alternatives):

- **Core** ☑
- Department Specific Elective ☐
- Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-401

Course Name: Dissertation

Brief Course Description:

Every student will undertake the following tasks: report writing, presentation and open viva-voce before the faculty members.

Contents	Marks
Report: A review work based on a research topic will be offered	15
Presentation on the report	15
A grand viva-voce will be conducted in presence of one/two external examiner(s)	20

Prerequisite(s) and/or Note(s): Graduate level mathematics

Course Objectives:

Knowledge acquired:

After completion of the course student will acquire the knowledge of specific research topic

Skills gained:

(1) Presentation skill
(2) Writing skill
(3) Communication skill

Competency developed:

(1) Research interest in a particular mathematics topic
(2) This will help to be a good researcher in future

Course Syllabus:

- Every student will undertake the following tasks: report writing, presentation and open viva-voce before the faculty members.
- Report: A review work based on a research topic will be offered.
- Presentation on the report.
- A grand viva-voce will be conducted in presence of one/two external examiner(s).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV☑**

Course Name: Graph Theory

Course Code: MATH-CC-402

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-402

Course Name: Graph Theory

Brief Course Description:

In this course, we deal with the fundamental concepts of graph theory and applications of graphs in different branches of science and real world problem. Course will cover the basic properties of Graph, subgraph and their representations, undirected and directed graphs, isomorphism of graphs, Eulerian graphs, Hamiltonian graphs, characterizations of trees with applications, bipartite graph and its characterization, planar and non-planar graphs, coloring of a graph, and matrix representation of graphs.

Prerequisite(s) and/or Note(s): Mathematical proof technique (Induction, proof by Contradiction), and linear algebra.

Course Objectives:

To understand the fundamental concepts of graph theory and its application in the different branches of science and to solve some practical problems

Knowledge acquired:

The students would gain knowledge about

(1) the undirected and directed graphs

(2) isomorphism of graphs, Eulerian graphs, Hamiltonian graphs

(3) trees and its various characterizations

(4) bipartite graph and its characterization

(5) planar and non-planar graphs

(6) colouring of a graph, matrix representation of graphs

(7) applications of graphs in different branches of science and real world problem

Skills gained:

(1) Develop algorithm for shortest path between two vertices

(2) Construct matching problem using bipartite graph and hence define a problem related to perfect matching

(3) Applying Fleury's algorithm to construct Eulerian graph

(4) Applying Kruskal's algorithm to construct minimum spanning tree

(5) Construct suitable techniques to colour a graph

Competency developed:

The students would be able to

(1) assimilate various graph theoretic concepts and familiarize with their applications.

(2) efficiency in handling with discrete structures

(3) efficiency in notions of matrix representation of graph, planarity

(4) efficiency in solving concrete graph colouring problems

(5) solve real world problems that can be modelled by graphs

Course Syllabus:

- Graph: Undirected graphs, directed graphs, basic properties of graphs, walks, paths, cycles, connected graphs, components of a graph, complete graph, complement of a graph.
- Trees: Basic properties and characterization, centres of trees, spanning trees, rooted tree, binary tree, Minimal Spanning tree, Kruskal's algorithm, bipartite graphs, characterization a bipartite graph,
- Euler and Hamiltonian graphs: Characterization, Konigsberg bridge problem, Petersen graph, Chinese-postman-problem, orientation in a directed graph, Eulerian directed graphs, Hamilton directed graphs.
- Cut vertices and cut edges, weighted graphs, Vertex and edge connectivity.
- Planar Graphs: Basic concepts, Euler's formula, polyhedrons and planar graphs, characterizations, planarity testing, Five-color-theorem, Dual of a planar Graph.
- Vertex and Edge colorings: vertex colouring of graphs, Chromatic number of graphs and its elementary properties, matrix representation of graphs, adjacency matrices of graphs and digraphs and their properties, path matrix, incidence matrices of graphs and digraphs and their properties.

Suggested Readings:

Graph Theory with Applications to Engineering and Computer Sciences,
N. Deo,
Prentice Hall of India.

Introduction to Graph Theory,
D. B. West,
Prentice-Hall of India/Pearson, (2009).

A First Look at Graph Theory,
J. Clark and D. A. Holton,
Allied Publishers Ltd., (1995).

Discrete Mathematical Structures with Applications to Computer Science,
J. P. Tremblay, R. Manohar,
McGraw Hill Book Co. (1997).

Graph Theory and Applications, New-Holland,
J. A. Bondy, U. S. R. Murty,
New York, (1976).

A Textbook of Graph Theory,
R. Balakrishnan, K. Ranganathan,
2nd edition, Springer, (2012).

Introduction to Graph Theory,
D. S. Malik, M. K. Sen and S. Ghosh,
Cengage Learning Asia, (2014).

Discrete mathematics with algorithms,
M. O. Albertson, J. P. Hutchinson,
John Wiley and Sons, (1988)

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Numerical Analysis

Course Code: MATH-CC-403

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-403

Course Name: Numerical Analysis

Brief Course Description:

Newton forward and backward interpolation formula, Central difference interpolation formula, Lagrange's Interpolation formula, Hermite Interpolation formula, Newton's divide difference interpolation formula. Least Square and Curve fitting procedure, Weighted least square approximations, Method of least square for continuous functions: orthogonal polynomials, Gram-Schmidt orthogonalization, Approximation of functions, Gauss Jordan, LU decomposition, Cholesky's decomposition, Gauss Jacobi, Gauss-Seidel method, successive over-relaxation method (SOR), Generalized Runge-Kutta methods (implicit and explicit), Predictor -Corrector Methods. Finite difference method for Laplace equation, heat equation, and the wave equation, forward in time centered in space (FTCS), Crank-Nicolson method.

Prerequisite(s) and/or Note(s): Students are supposed to have learn Real analysis, algebra, Calculus

Course Objectives:

Knowledge acquired:

After completion of this course, students will be able to gain

(1) ways of solving complicated mathematical problems numerically

(2) the numerical methods of solving the non-linear equations, interpolation, differentiation, and integration

(3) understanding of the several errors and approximations in numerical methods, several available solutions of equations

(4) ability to know about convenient numerical softwares

Skills gained:

(1) To improve the student's skills in numerical methods by using the numerical analysis software and computer facilities.

(2) Demonstrate understanding of common numerical methods and how they are used to obtain approximate solutions

(3) Apply numerical methods to obtain approximate solutions to mathematical problems

(4) Evaluate the accuracy of common numerical methods and Implementation of numerical methods in physical problems

Competency developed:

(1) Having a ground acquired in this course, students are able to apply in other fields also

(2) Give students an opportunity to develop and present an independent project

Course Syllabus:

- Errors in Polynomial Interpolation, Finite differences, Interpolation with evenly spaced points: Newton forward and backward interpolation formula, Central difference interpolation formula (Gauss's formula, Stirling's formula, Bessel's formula, Everett formula, Relation between Bessel's and Everett's formula), Interpolation with unevenly spaced points: Lagrange's Interpolation formula, Hermite Interpolation formula, Newton's divide difference interpolation formula, Interpolation by iteration, inverse interpolation, double interpolation.

- Least Square and Curve fitting procedure, Weighted least square approximations, Method of least square for continuous functions: orthogonal polynomials, Gram-Schmidt orthogonalization, Approximation of functions: Chebyshev polynomials, Economization of Power Series, Fourier Approximation: Fourier Transformation, Discrete Fourier Transformation, Fast Fourier Transform, Cooley Turkey Algorithm.Linear, Quadratic, Cubic Spline, Cubic B-spline.
- Gauss Jordan, LU decomposition, Cholesky's decomposition, Gauss Jacobi, Gauss-Seidel method, successive over-relaxation method (SOR), Solution of Tridiagonal System, Ill conditioned system, Eigenvalues of a symmetric tridiagonal system. Householder's method, QR method, Power method, Jacobi method. Generalized Runge Kutta methods (implicit and explicit), Predictor -Corrector Methods: Adam-Moultons method, Milne's method, shooting method, and Galerkin method.
- Finite difference method for Laplace equation, heat equation, and the wave equation, forward in time centered in space (FTCS), backward in time centered in space (BTCS), Crank-Nicolson method, ADI method, general five-point formula, etc.

Suggested Readings:

Numerical Methods for Scientific and Engineering Computations,
M. K. Jain, S. R. K. Iyenger and R. K. Jain,
New Age International Publication (P) Ltd, New Age International (P) Limited, (2003)

An Introduction to Numerical Analysis (Second Edition),
K. E Atkinson
John Wiley and Sons -(2008).

Numerical Methods for Scientists and Engineers,
R. W. Hamming,
Dover publications, 2nd Revised Edition (1986)

An introduction to numerical methods and analysis (Second Edition),
J. F. Epperson,
John Wiley and Sons (2013).

Numerical Analysis: Mathematics of Scientific Computing (The Sally Series; Pure and Applied Undergraduate Texts, Vol. 2),
D. Kincaid, W. Cheney,
American Mathematical Society; 3rd Revised Edition, (2002)

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Numerical Problem solving by Computer Programming (Practical)

Course Code: MATH-CC-404

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☑

Department Specific Elective ☐

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-CC-404

Course Name: Numerical Problem Solving by Computer Programming (Practical)

Brief Course Description:

C Programming: An overview of computer programming languages, Operators and Expressions Conditional Branching: Looping and nested looping, infinite loops, header file and include directive, macro substitution and conditional compilation, scanf, printf and various format specifiers, standard C library functions, arrays and memory.

Pointer arithmetic, sorting algorithms, passing arguments to a function, pointers to functions, passing arrays as function arguments, recursion, main () function. opening and closing a file, reading from a file and writing to a file, random access and error handling. Interpolation: Newtown forward, Newtown backward, Stirling, Lagrange, Divided Differences. Differentiation: using interpolated polynomials. Integration: Trapezoidal Method, Simpson Method, Romberg Method, Gauss Quadrature Method. Matrix inversion: Gauss Jordan method. Largest eigenvalue and corresponding eigen vector of a square matrix: Power method. System of Linear equation: Gauss Elimination method, Gauss-Jacobi method Gauss-Seidal method. O.D.E.: Runge-Kutta method, Milne's method, Adams method. P.D.E. (finite difference method): Laplace, Parabolic, and Hyperbolic.

Prerequisite(s) and/or Note(s): Numerical analysis

Course Objectives:

Knowledge acquired:

(1) Basic ideas about computer programming language

(2) Fundamental data types, operators and expressions, conditional branching used in C

(3) C-functions (declaring and calling a function), arrays (one dimensional and multidimensional), pointers (Accessing array elements through pointers)

(4) Opening and closing a file, reading from a file and writing to a file

(5) Solving numerical problems using C-programming

Skills gained:

(1) Efficiency in handling with data types, C-operators, expression in C, conditional branching, looping

(2) Construct C-functions, use of Standard C library functions

(3) Efficiency in handling with arrays, pointers, C-file

(4) Efficiency in solving numerical problems such as interpolation, differentiation, integration, matrix problem, ODE, PDE etc. using C- programming

Competency developed:

(1) Ability to understand syntax in C (data types, arrays, pointers, C-files, C-functions, etc.)

(2) Ability to solve various numerical problems occurring in applied mathematics, theoretical physics, and biological science

Course Syllabus:

- C Programming: An overview of computer programming languages, modular programming and program development cycle, character set, keywords and identifiers, variables and Constants.

- Fundamental Data Types: Int, short, long; float, double; char; type conversion and casting; Operators and Expressions: arithmetic operators, relational operators, logical operators, assignment operators, increment and decrement operators, bitwise manipulation operators, size of operator, conditional operator; operator precedence and associativity; void data type.
- Conditional Branching: if, if-else, switch; Looping and nested looping, for, while, do-while; break and continue, goto, infinite loops, header file and include directive, macro substitution and conditional compilation, scanf, printf and various format specifiers, standard C library functions, declaring, initializing and using arrays in programs; arrays and memory; one dimensional and multidimensional arrays; character arrays and strings, pointer arithmetic, accessing array elements through pointers, arrays of pointers, pointers to pointers, sorting algorithms, passing arguments to a function, declaring and calling a function; pointers to functions, passing arrays as function arguments, recursion, main() function. opening and closing a file, reading from a file and writing to a file, random access and error handling.
- Interpolation: Newtown forward, Newtown backward, Stirling, Lagrange, Divided Differences.
- Differentiation: using interpolated polynomials.
- Integration: Trapezoidal Method, Simpson Method, Romberg Method, Gauss Quadrature Method.
- Matrix inversion: Gauss Jordan method.
- Largest eigenvalue and corresponding eigen vector of a square matrix: Power method.
- System of Linear equation: Gauss Elimination method, Gauss-Jacobi method Gauss-Seidal method.
- O.D.E.: Runge-Kutta method, Milne's method, Adams method.
- P.D.E. (finite difference method): Laplace, Parabolic, and Hyperbolic.

Suggested Readings:

Programming with C,
B. Gottfried,
Tata McGraw-Hill, (2002).

Programming in ANSI C,
E. Balagurusamy,
Tata Mcgraw Hill, (2002).

The C Programme Language,
B. W. Kernighan, D. M. Ritchie,
2nd Edition (ANSI features), Prentice Hall, (1989).

Y. P. Kanithkar,
Let Us C- BPB Publication, (2002).

Numerical Methods For Scientific And Engineering Computation,
M. K. Jain,
Wiley, (2003).

Numerical Solution of Partial Differential Equations by Finite Difference Methods,
G. D. Smith,
Clarendon Press,(1985).

Programming with C,
K. R. Venugopal, S. R. Prasad,
Tata-McGraw Hill.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Boundary Integral Equations

Course Code: MATH-DSE-401-01

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

- Core ☐
- **Department Specific Elective ☑**
- Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number:

Course Code: MATH-DSE-401-01

Course Name: Boundary Integral Equations

Brief Course Description:

The foundation of this method is a reformulation of the partial differential equation as an integral equation. In many cases, the resulting integral equation can rapidly be solved to very high accuracy, and in an entirely stable manner. The computational speed of these methods compares favorably with other numerical techniques for partial differential equations. The most dramatic speed-up occurs for problems that can be reformulated as integral equations defined on the boundary alone.

Prerequisite(s) and/or Note(s): Partial Differential Equations

Course Objective:

Knowledge acquired:

(1) Design a solution methodology for a collocation scheme discretizing a boundary integral equation to solve the Laplace or Stokes equations for 2D geometries and a simple 3D-geometry. Motivate the choices made and discuss the accuracy of the solution

(2) Identify strengths and weaknesses about boundary integral methods. Argue about if a boundary integral method is advantageous to use for a specific problem, and how it compares to other well-established solution methods

Skills gained:

(1) Formulate the Laplace and Stokes equations as boundary integral equations (BIE)

(2) Explain key concepts of the mathematical theory for integral equations (e.g. properties of integral equations of the first and second kind, practical consequences) and of theory specific to Stokes flow (e.g. Lorentz reciprocal theorem)

(3) Work with complex variable formulations of integral equations in 2D and build discretizations based on these

(4) Explain what difficulties arise in the design of quadrature formulas for BIEs, and some techniques that can remedy these difficulties

Competency developed:

One can deal problems with infinite or semi-infinite domains, e.g., so-called exterior domain problems: there, although only the finite surface of the infinite domain has to be discretized, the solution at any arbitrary point of the domain can be found after determining the unknown boundary data

Course Syllabus:

- Green representation formula, Green's function of Laplace equationin1D, 2D, and 3D, Green's function of Helmholtz equation, integral representation. Hypersingular integrals, generalized single and double layer representations, boundary potentials.
- Laplace and Poisson problems, boundary integral equations of the Dirichlet and Neumann problems (interior and exterior), mixed and Robin Boundary Value Problems, interface problem, Helmholtz equation with Dirichlet and Neumann Boundary Value Problem, low-frequency behaviour.
- Calderon’s projector, Boundary Value Problems, Boundary Integral Equations, Lame` equations: Dirichlet, Neumann, and mixed Boundary Value Problems, derivation of the

Boundary Element Method in 2D and 3D, the Boundary Integral Method for Stokes equation, inhomogeneous, nonlinear, and time dependent problems.

Suggested Readings:

Boundary Integral and Singularity Methods for Linearized Viscous Flow,
C. Pozrikidis,
Cambridge university press.

A Practical Guide to Boundary Element Methods with the Software Library BEMLIB,
C. Pozrikidis,
CRC Press.

The Fast Solution of Boundary Integral Equations,
S. Rjasanow, and O. Steinbach,
Springer Science & Business Media.

Boundary Integral Equations,
G. C. Hsiao, and W. L. Wendland,
Springer.

Analysis IV-Linear and Boundary Integral Equations,
V. Maz'ya, and A. Soloviev,
Springer- Verlag.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Mathematical Ecology

Course Code: MATH-DSE-401-02

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-02

Course Name: Mathematical Ecology

Brief Course Description:

The course 'Mathematical Ecology' deals with several mathematical models of population biology or Ecology and mathematical theory of epidemics. Concepts of deterministic and stochastic, single species population models, Interactions between two species. Biological mechanisms responsible for time-delay, time-delayed H-P model together with their stability analysis.

Introduction, some basic definitions of epidemic model, Kermack-McKendrik threshold theorem, control of an epidemic, stochastic epidemic model without removal, models having multiple infections, stochastic epidemic model with removal, stochastic epidemic model with carriers. Extensions of SIR model with different case studies.

Prerequisite(s) and/or Note(s): Students are supposed to have learned dynamical system analysis, techniques for solution of linear and nonlinear differential equations, Numerical Methods

Course Objectives:

Knowledge acquired:

After completion of this course, Students will be able to gain the knowledge of

(1) Mathematical model of species population, Host-Parasite interaction and logistic model with general delay function.

(2) Stability analysis of mathematical model in biology, Application of Lyapunov functions, periodic orbits, limit cycles, attracting and invariant set, Poincare-Bendixson theorem and Poincare map in biology.

(3) Introduction of Mathematical theory of epidemics, Kermack-Mc Kendrik threshold theorem, recurring epidemic model, Epidemic model with multiple infections.

(4) Bifurcation analysis such as Saddle-node bifurcation, Pitchfork bifurcation, period doubling bifurcation, period doubling route to chaos, Hopf bifurcation and its application in mathematical biology

Skills gained:

Students will have gained the following skills

(1) Formulation of Mathematical model in biology and their analysis through finding critical points, the nature of critical points, and portray the time series graphically.

(2) Concept of stochastic epidemic model with removal, stochastic epidemic model with carriers, immigration and emigration

(3) Some case studies on simple extension of SIR model (i) Loss of immunity, (ii) Inclusion of immigration and emigration, (iii) Immunization, SIR endemic disease model.

Competency developed**:**

Students will be able to developed

(1) Mathematical model of epidemic with different infectious diseases

(2) The SIR model in real-life problems

Course Syllabus:

Mathematical Models of Population Biology or Ecology:

- Deterministic and stochastic, single species population models, P-V logistic equation, population growth model- an age structured model.
- Interactions between two species: Host-Parasite type of interactions, competitive type of interactions.
- Trajectories of interactions of H-P and competitive types between two species, effect of migration on H-P interactions, some consequences of Lotka-Volterra equations, generalized L-V equations, constant of motion in the dynamical system, stochastic processes and need of stochastic models, pure birth process, pure death process, birth and death process, linear birth-death-immigration-emigration processes, effects of both immigration and emigration on the dynamics of population.
- Biological mechanisms responsible for time-delay, discrete and continuous time-delay, the single species logistic model with the effect of time-delay, stability of equilibrium position for the logistic model with general delay function, stability of logistic model for discrete time lag, time-delayed H-P model together with their stability analysis.

Mathematical Theory of Epidemics:

- Introduction, some basic definitions, simple epidemic model, general epidemic model, Kermack-Mc Kendrik threshold theorem, recurring epidemic model, a comparative study of these models.
- Control of an epidemic, stochastic epidemic model without removal, models having multiple infections. stochastic epidemic model with removal, immigration and emigration, special discussion on the stochastic epidemic model with carriers.
- Simple extensions of SIR model: Different case studies (i) Loss of immunity, (ii) Inclusion of immigration and emigration, (iii) Immunization, SIR endemic disease model.

Suggested Readings:

Mathematical Biology,
J. D. Murray,
Springer-Verlag, Berlin, (1989).

Dynamical Systems in Population Biology,
X. Q. Zhao,
Canadian Mathematical Society, (2003)

Mathematical Models in Biology and Medicine,
J. N. Kapur,
East West Press Pvt Ltd, (1985)

Mathematical Models,
R. Habermann,
Prentice Hall, (1977).

An Introduction to Mathematical Ecology,
E. C. Pielou,
Wiley, New York, (1977).

Foundation of Mathematical Biology (vol. I& II),
R. Rosen,
Academic Press, (1972)

Elements of Mathematical Ecology,
M. Kot,
Cambridge Univers ity Press, (2003).

Infectious Diseases of Humans,
R. M. Andersson, R. M. May,
Oxford University Press, (1992)

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Bio-fluid Mechanics

Course Code: MATH-DSE-401-03

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course name: Bio-fluid Mechanics

Course Code: MATH-DSE-401-03

Brief Course Description:

The course 'Bio-fluid Mechanics' deals with studies on the mechanics of blood vessels, structure and functions of blood vessels, mechanical properties, viscoelasticity, linear discrete viscoelastic (spring-dashpot) models. Constituents of blood, structure and functions of the constituents of blood, mechanical properties of blood, equations of motion applicable to blood flow, non-Newtonian fluids, steady non-Newtonian fluid flow, Fahraeus-Lindqvist effect, pulsatile flow, blood flow through arteries with mild stenosis, shear stress on surface of the stenosis, two-layered flow in a tube with mild stenosis. Large deformation theory, various forms of strain energy functions, Green's deformation and Lagrangian strain tensors, constitutive equations for blood vessels, equations of motion for the vascular wall.
Fick's laws of diffusion, one-dimensional diffusion model and its solution, various modifications of diffusion equation to diffusion-reaction models arising in pharmacokinetics and ecology. Basic equations for a circular-duct and a parallel-plate dialyser, Peclet number, Sherwood number, solutions of basic equation for a circular-duct dialyser by (i) separation of variables method and (ii) Galerkin's method, solution for parallel-plate dialyser.

Prerequisite(s) and/or Note(s): Students are supposed to have learned fluid mechanics, techniques for solution of linear and nonlinear differential equations, Numerical Methods

Course Objectives:

Knowledge acquired:

After completion of this course, Students will be able to gain the knowledge of

(1) the mechanics of blood vessels, structure and functions of blood vessels, mechanical properties, equations of motion applicable to blood flow, non-Newtonian fluids, steady non-Newtonian fluid flow

(2) concept of Fahraeus-Lindqvist effect, pulsatile flow, blood flow through arteries with mild stenosis, shear stress on surface of the stenosis, two-layered flow in a tube with mild stenosis

(3) Fick's laws of diffusion, one-dimensional diffusion model and its solution

(4) diffusion-reaction models arising in pharmacokinetics and ecology

Skills gained:

Students will have gained the following skills

(1) Formulation of mathematical model in hemodynamics and their analysis through finding analytical solutions and numerical solutions

(2) Application of some Newtonian and non-Newtonian fluids used in various industry

(3) Fundamental equations to model a circular-duct and a parallel-plate dialyser

Competency developed**:**

Students will be able to developed some mathematical model of fluid mechanics problems arises in human physiology

Course Syllabus:

Arterial Biomechanics:

- Importance of studies on the mechanics of blood vessels, structure and functions of blood vessels, mechanical properties, viscoelasticity, linear discrete viscoelastic (spring-dashpot) models: Maxwell fluid, Kelvin solid, Kelvin chains and Maxwell models, creep compliance, relaxation modulus, hereditary integrals, Stieltjes Integrals.
- Constituents of blood, structure and functions of the constituents of blood, mechanical properties of blood, equations of motion applicable to blood flow, non-Newtonian fluids - Power law, Bingham Plastic, Herschel-Bulkley and Casson fluids, steady non- Newtonian fluid flow in a rigid circular tube, Fahraeus-Lindqvist effect, pulsatile flow in both rigid and elastic tubes, blood flow through arteries with mild stenosis, shear stress on surface of the stenosis, two-layered flow in a tube with mild stenosis.
- Large deformation theory, various forms of strain energy functions, the base vectors and metric tensors. Green's deformation and Lagrangian strain tensors, cylindrical model, constitutive equations for blood vessels, equations of motion for the vascular wall.

Biological Diffusion and Diffusion-Reaction Models:

- Fick’s laws of diffusion, one-dimensional diffusion model and its solution, some solutions of two dimensional diffusion equation, various modifications of diffusion equation to diffusion-reaction models arising in pharmacokinetics and ecology.
- Hemodialyzer and dialysis of blood: Basic equations for a circular-duct and a parallel-plate dialyser, Peclet number, Sherwood number, solutions of basic equation for a circular-duct dialyser by (i) separation of variables method and (ii) Galerkin’s method, solution for parallel-plate dialyser.

Suggested Readings:

Mathematical Models in Biology and Medicine**,**
J.N Kanpur
East West Press Pvt Ltd, (1985).

Biomechanics of Soft Biological Tissues,
Y. C. Fung
Springer, New York, (1993)

Mathematical Models,
R. Habermann
Prentice Hall (1977).

An Introduction to Mathematical Ecology,
.E. C. Pielou
Wiley, New York, (1977)

Foundation of Mathematical Biology (vol. I& II),
R. Rosen
Academic Press, (1972)

Viscoelasticity
W. Flugge,
Springer-Verlag, (1975)

The Physics of Pulsatile Flow,
M. Zamir, E L Ritman
Springer, (2000)

Blood Flow in Arteries,
D. A. MacDonald
The Williams and Wilkins Company, Baltimore (1974)

Biofluid Mechanics,
J.N. Mazumdar
World Scientific (2015)

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV☑**

Course Name: General Theory of Relativity and Cosmology

Course Code: MATH-DSE-401-04

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-04

Course Name: General Theory of Relativity and Cosmology

Brief Course Description:

General Theory of Relativity: Geometry of space-time, Symmetry, Homogeneity and isotrophy, Energy momentum tensor, Energy conditions, Einstein field equation, Schwarzschild solution, Weak field approximation of gravity, Experimental test of general relativity, Black holes,

Cosmology: FLRW universe, Cosmological principle, Friedmann equation and acceleration equation, Cosmological constant, Cosmological parameters, Cosmological observations, Various cosmological models, Inflation and very early universe, Dark matter, Dark energy.

Prerequisite(s) and/or Note(s): The students are assumed to have studied differential geometry and classical mechanics at Master level, Special theory of relativity and ordinary differential equations and statistics.

Course Objectives:

Knowledge acquired:

Student should be able to gain the following knowledge of:

(1) Geometry of space-time and definition of Energy momentum tensor, Structure of Einstein field equation
(2) Solution of Einstein field equation, definition and types of Black holes,
(3) Cosmological studies of Universe, Cosmological models of Universe, Cosmological parameters, Cosmological observations,
(4) Definition of Dark energy, Dark matter, different dark energy models

Skills gained:

(1) Students will be able to apply knowledge of General Theory of Relativity to Cosmological study
(2) Students will be able to model different type of cosmological models and to compare them to present observational data

Competency developed:

After completion of the course students will be able
(1) to understand the cosmic structure and evolution of the universe and compare to the observational data
(2) to construct theoretical models and fitting with the observational data

Course Syllabus:

- Geometry of curved space-time, Equivalence principle.
- Space-time symmetries: killing vectors & their properties. Homogeneity & isotropy, Curvature of maximally symmetric spaces.
- Energy-momentum tensor, energy conditions, perfect fluid.
- Einstein's field equations: Approach of Heuristic derivation and from Action Principle, Schwarzschild solution, Birkhoff's theorem, singularities, Weak field approximation of gravity: Newtonian limit, Geodesics in Schwarzschild space-time.
- Experimental test of General Relativity: Deflection of light, precession of planetary orbits, Radar echo delay, Gravitational lenses.
- Black Holes: Schwarzschild black hole, mass, charge and spin; Event horizon, Apparent horizon. Kerr Black hole (rotating).

- Cosmology**:** Homogeneous and isotropic space-time, FLRW universe, Cosmological principle, Weyl's postulate,
- Cosmic dynamics: Friedmann equation, acceleration equation, Hubble's law in relativistic cosmology, Gravitational red-shift and Cosmological red-shift.
- Cosmological model of universe: Evolution of energy density of the matter content, model with vanishing and non-vanishing cosmological constant, The Friedmann dust universe, Open and Closed model of universe, Empty universe, The Einstein static model, the de Sitter model, Evolution of universe with multiple matter content.
- Cosmological parameters: Hubble parameter, Luminosity distance, Angular-diameter distance, deceleration parameter, equation of state parameter.
- Inflation and very early universe: The flatness problem, The Horizon problem, The Monopole problem, The inflation solution.
- Dark Matter: Observational evidences, Visible matter, Dark matter in galaxies, Dark Matter in clusters, Gravitational lensing.
- Dark Energy: Failure of Standard Cosmological model: Theoretical introduction to Dark Energy, Cosmological Constant Λ as Dark Energy, ΛCDM, Cosmological constant problem and coincidence problem, Dynamical Dark Energy models based on scalar field: Quintessence, k-essence, tachyon, phantom.

Suggested Readings:

Introduction to General Relativity,
Ryder,
Cambridge University Press, 2009.

A First Course in GENERAL RELATIVITY,
B. F. Schutz,
Cambridge University Press, 2009

A Relativist's Toolkit: The Mathematics of Black-Hole Mechanics**,**
E. Poisson,
Cambridge University Press, 2004.

An introduction to general relativity: Space-time and Geometry,
S. M. Carroll,
Pearson, Addison Wesley, 2004.

Introducing Einstein's Relativity,
R. d' Inverno,
Oxford University Press 2012.

A Treatise on Differential Geometry and its role in Relativity Theory-Book
S. Chakraborty,
ref: arXiv:1908.10681[gr-qc] (2019).

General Relativity, Astrophysics and Cosmology,
A. K. Raychaudhury, S. Banerji and A. Banerjee,
Springer Science & Business Media, 2003.

Introduction to Cosmology,
B. Ryden,
Cambridge University Press, 2017.

Modern Cosmology,
S. Dodelson,

Elsevier Science Publishing Co Inc. 2020.

An Introduction to cosmology,
J. V. Narlikar,
Cambridge University Press, 2002.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Lie Theory of Ordinary and Partial Differential Equations

Course Code: MATH-DSE-401-05

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-05

Course Name: Lie Theory of Ordinary and Partial Differential

Brief Course Description:

The course 'Lie Theory of Ordinary and Partial Differential' deals with Lie Group of Transformations, Infinitesimal Transformations, extended transformations, multi-parameter Lie group of transformations, invariance of second and higher ODEs under point symmetries, reduction of order of ODEs, invariance of a PDE, determining equations for symmetries of a k^{th}-order PDE, Invariant Solution of PDEs, determining equations for symmetries of a system of PDEs, application to Boundary Value Problems

Prerequisite(s) and/or Note(s): Students are supposed to have learned linear algebra, vector space, ordinary and partial differential equations

Course Objectives:

After completion of this course, Students will be able to gain the knowledge of

Knowledge acquired:

(1) approaches to modelling by differential equations, basic theorems on existence of solutions and methods for analytical solving linear and non-linear ordinary and partial differential equations.

(2) the terminology in group analysis of differential equations.

(3) Solving technique by reducing the order of ODEs.

(4) Boundary values problems and their solution by Lie group of transformation

Skills gained:

(1) develop skills in using Lie group analysis for solving nonlinear ordinary and partial differential equations.

(2) show analytic skills and working knowledge in Lie's integration methods.

(3) Ability to finding determining equations for symmetries of a kth-order PDE

Competency developed:

Show competence in the field of ordinary and partial differential equations.

Course Syllabus:

- Lie Group of Transformations and Infinitesimal Transformations: Introduction, Lie group of transformations, infinitesimal transformations, point transformations and extended transformations (prolongations), multi-parameter Lie group of transformations and Lie algebras, mappings of curves and surfaces, local transformations.
- Ordinary Differential Equations: Elementary examples, first order ODEs, invariance of second and higher order ODEs under point symmetries, reduction of order of ODEs under multi-parameter Lie group of point transformations.
- Invariance of a PDE: Introduction, determining equations for symmetries of a k^{th}-order PDE, invariance of scalar PDE, elementary examples.
- Invariant Solution of PDEs: Invariant solutions, example, invariance for a system of PDEs, determining equations for symmetries of a system of PDEs, examples,

- Application to Boundary Value Problems: Formulation of invariance of a Boundary Value Problem for a scalar PDE, incomplete invariance for a linear scalar PDE, incomplete invariance for a linear system of PDEs.

Suggested Readings:

Symmetry and Integration Methods for Differential Equations,
G. W. Bluman, S. C. Anco,
Springer.

Application of Lie Groups to Differential Equations,
P. J. Olver,
Springer.

Elementary Lie Group Analysis and Ordinary Differential Equations,
N. H. Ibragimov,
John Wiley & Sons.

Differential Equations: Their Solution Using Symmetries,
H. Stephani,
Camb. Univ. Press.

Department Name:	Mathematics
Program Name:	PG in Mathematics
Program Code:	

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV☑**

Course Name:	Nonlinear Optimization
Course Code:	MATH-DSE-401-06
Course Credit:	2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

- Core ☐
- **Department Specific Elective** ☑
- Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-06

Course Name: Nonlinear Optimization

Brief Course Description:

This course is aimed at upper level graduate students in Engineering, Operations Research, Management Science, Applied Mathematics, Computer Science and Economics. The objective is to expose the student to different types of nonlinear programming problems, and to the various algorithms used to solve these.

Prerequisite(s) and/or Note(s):

(1) Differential Calculus
(2) Vectors, Matrices, and linear algebra.
(3) Familiarity with basic concepts from real analysis such as sets, functions, continuity, etc.

Course Objective:

Knowledge acquired:

A student:

(1) can explain what a continuous optimization problem is and how it can be solved.

(2) can explain the mathematical theory behind the solution algorithms for continuous optimization problems.

(3) can analyze the effectivity of solution methods for continuous optimization problems.

(4) can discuss the connection to Machine Learning.

(5) can analyze the effectivity of solution methods for continuous optimization problems.

(6) can discuss the connection to Machine Learning.

Skills gained:

(1) Recognize and formulate a mathematical optimization problem.

(2) Analyze and implement the gradient descent method, Newton's method, the trust-region method and the augmented Lagrangian method, among others.

(3) Establish and discuss local and global convergence guarantees for iterative algorithms.

(4) Exploit elementary notions of convexity and duality in optimization.

(5) Apply the general theory to particular cases.

(6) Prove some of the most important theorems studied in class.

Competency developed:

Having successfully completed this module you will be able to:

(1) demonstrate knowledge and understanding of nonlinear programming solution algorithms

(2) demonstrate knowledge and understanding of nonlinear programming modelling techniques

Course Syllabus:

- Convex set, Convex function, Generalized convex functions. Fritz John and Karush- Kuhn – Tucker optimality condition, duality, Convex programming problems, Quadratic programming, Fractional programming, Separable programming, Non-linear integer programming.
- Constrained Optimization: One dimensional search methods, Multi-dimensional search methods. Unconstrained optimization: Conjugate gradient method, Generalized reduced gradient methods, Method of feasible direction.

Suggested Readings:

Graph Theory with Applications to Engineering and Computer Science,
N. Deo,
PHI.

Engineering Optimization: Theory and Practice,
S. S. Rao,
New Age International Pvt. Ltd., 3rd Edition, (1998).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV☑**

Course Name: Computational Statistics

Course Code: MATH-DSE-401-07

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number:

Course Code: MATH-DSE-401-07

Course Name: Computational Statistics

Brief Course Description:

Computational statistics is a branch of mathematical sciences focusing on efficient numerical methods for problems arising in statistics. The goal of this course is to provide students an introduction to a variety of modern computational statistical techniques and the role of computation as a tool of discovery. Topics include numerical optimization in statistical inference including expectation-maximization (EM) algorithm, Fisher scoring, gradient descent and stochastic gradient descent, etc., numerical integration approaches include basic numerical quadrature and Monte Carlo methods, and approximate Bayesian inference methods including Markov chain Monte Carlo, variationally inference and their scalable counterparts, with applications in statistical machine learning, computational biology and other related fields. Additional topics may vary. Coursework will include computer assignments.

Prerequisite(s) and/or Note(s): Familiarity with computer system, statistics and numerical methods

Course Objectives:

Knowledge acquired:

(1) Reproduce and apply the fundamental theorems of random variate generation.

(2) Simulate variates and vectors from the most common distributions.

(3) Evaluate the quality of a random number generator.

(4) Use statistical software to perform statistical analysis

Skills gained:

(1) Apply the basic principles of variance reduction.

(2) Simulate complex systems and investigate their properties.

(3) Use simulation to approximate integrals.

(4) Use simulation to compute p-values and confidence intervals.

(5) Investigate properties of statistical procedures and estimators using simulation.

Competency developed:

(1) Perform programming relevant to the content of the course in the statistical package used in the course.

(2) Identify and interpret relevant information in the output of the statistical package used in the course.

(3) Plan and implement a statistical simulation study in an efficient way

Course Syllabus:

- Analysis of Variance, one-way and two-way classification, Concept of design of experiment. Some standard designs: completely randomized design, randomized block design, Latin Squares, Graeco Latin Squares, and factorial designs, confounding and blocking in factorial designs, fractional factorial designs.

- Simple and multiple regression models. Classical techniques of time series analysis, smoothing and decomposition. Analysis of covariance model.

Suggested Readings:

Computational Statistics,
G. H. Givens, Jennifer A. Hoeting,
John Wiley & Sons, (201 2).

Handbook of Computational Statistics: Concepts and Methods,
J. E. Gentle, W. K. Härdle, Y. Mori,
Springer Science & Business Media, (2012).

Computational Statistics,
J. E. Gentle,
Springer Science & Business Media, (2009).

Computational Statistics Handbook with MATLAB,
W. L. Martinez, A. R. Martinez,
CRC Press, (2015).

Department Name:	Mathematics
Program Name:	PG in Mathematics
Program Code:	

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name:	Signed Measure and Product Measure
Course Code:	MATH-DSE-401-08
Course Credit:	2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-08

Course Name: Signed Measure and Product Measure

Brief Course Description:

Signed measure spaces, Monotone convergence theorem for signed measure, Hahn decomposition theorem for signed measure, Jordan decomposition of a signed measure, Lebesgue decomposition theorem, Radon-Nikodym theorem.
Product measure and product measurable spaces, Fubini's theorem and Tonelli's theorem.

Prerequisite(s) and/or Note(s): Extended Real Numbers, Infinite Series, Abstract Lebesgue Measure

Course Objectives:

Knowledge acquired:

(1) Concepts of signed measure on a σ-algebra

(2) Decomposition of signed measure space and signed measure

(3) Absolute continuity and mutual singularity

(4) Product measure spaces

Skill gained:

(1) Hahn Decomposition, Jordan decomposition, and Lebesgue decomposition.

(2) Solving problems on absolute continuity and mutual singularity

(3) Calculate product measure by integrals

Competency developed:

(1) Realizing importance of Radon-Nykodim theorem

(2) Fubini's theorem and Tonell'is theorem and their application

Course Syllabus:

- Definition and examples, signed measure spaces, signed measure as the integral of a semi-integrable measurable function, signed measure as the difference of two positive measures, partial monotonicity of signed measure, monotone convergence theorem for signed measure.
- Decomposition of signed measure, positive, negative and null sets in a signed measure space, Hahn decomposition theorem, mutual singularity of two signed measures, Jordan decomposition of a signed measure, relation between Hahn and Jordan decompositions, Jordan decomposition theorem, total variation measure, theorems exhibiting connection between mutual singularity and total variation, absolute continuity of a signed measure relative to a position measure; basic results, Lebesgue decomposition theorem, uniqueness of Lebesgue decomposition, Radon-Nikodym theorem.
- Product measure and product measurable spaces, estimation of product measure in terms of integrals, Fubini's theorem and Tonelli's theorem.

Suggested Readings:

Lectures on Real Analysis,
J. Yeh,
World Scientific.

Real analysis,
H. L. Royden,
Macmillan Publishing Co., Inc. 4th Edition, (1993).

Measure and integration**,**
S. K. Berberian,
Chelsea Publishing Company, NY, (1965).

Measure Theory and integration,
G. de Barra,
Wiley Eastern Ltd. (1981).

The Elements of Integration,
R. G. Bartle,
John Wiley & Sons, Inc. New York, (1966).

An Introduction to Measure and Integration**,**
I. K. Rana,
Narosa Publishing House, Delhi (1999).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☑ Semester IV ☐

Course Name: Topological Groups

Course Code: MATH-DSE-401-09

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? **YES** ☑ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? **YES** ☑ NO ☐

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☑

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

Kakutani's theorem and relevant results have been introduced to study metrizability of topological groups. Matrix groups and their topological properties are good addition to this syllabus.

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-09

Course Name: Topological Groups

Brief Course Description:

Deals with topics in Topological groups. In particular, the course will cover definition and examples of topological groups, subgroups and direct product of topological groups, metrizability of topological groups, connectedness in topological groups, compactness and local compactness in topological groups and related topics.

Prerequisite(s) and/or Note(s): Upon completion of the course, students are assumed to have studied Point Set Topology and Algebra at Graduate Level.

Course Objectives:

Knowledge acquired:

How to mix algebraic group structure with topological structure and its application.

Skills gained:

(1) Use of topological properties to know algebraic properties and
(2) Topological properties via algebraic properties.

Competency Developed:

Applications of Point-Set Topology towards extension of the study of Algebra.

Course Syllabus:

- Definition and examples of topological groups, Topologies generated by characters, Pseudonorms and invariant pseudometrics in a group, Function spaces as topological groups, Transformation groups, Subgroups and direct product of topological groups, Quotients of topological groups, initial and final topologies, Separation axioms, closed subgroups.
- Metrizability of topological groups; Kakutani's theorem and relevant results; Connectedness in topological groups, Group topologies determined by sequences.
- The Zariski topology and the Markov topology, The Markov topology of the symmetric group, Existence of Hausdorff group topologies, Extension of group topologies, Cardinal invariants of topological groups, Completeness and completion of topological groups,
- Compactness and local compactness in topological groups: examples, specific properties of compactness and local compactness, general properties (the open mapping theorem, completeness, etc.), compactness vs connectedness, Properties of $\mathbb{R}^n$ and its subgroups, the closed subgroup of $\mathbb{R}^n$, elementary LCA groups and Kronecker's theorem, on the structure of compactly generated locally compact abelian groups.
- Matrix groups and their topological properties.

Suggested Readings:

Introduction to topological groups,
D. Dikranjan.

Topological Rings,
S. Warner
Elsevier Science Publishers.

Topological Vector Spaces (Lecture notes),
I. F. Wilde

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Analytic Number Theory

Course Code: MATH-DSE-401-10

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-10

Course Name: Analytic Number Theory

Brief Course Description:

MATH-DSE-401-10 deals with the basics of analytic number theory, which includes topics like Euler's summation formula, Tauberian Theorems, Dirichlet's Theorem for primes in an arithmetic progression, characters of finite abelian groups, Riemann zeta function.

Prerequisite(s) and/or Note(s):

(1) Undergraduate level mathematics
(2) Elementary Number Theory

Course Objectives:

Knowledge acquired:

(1) Euler's summation formula
(2) Characters of a finite abelian group, Dirichlet Characters
(3) Equivalent forms of Prime Number Theorem
(4) Riemann zeta function and Dirichlet L-function
(5) Dirichlet's Theorem for primes in an arithmetic progression

Skills gained:

(1) Ability to find the average order of various arithmetical functions
(2) Ability to deal with different problems in Number theory such as problems related to primes in an Arithmetic Progression, L-functions etc.

Competency Developed:

Basic preparation for research in various areas of pure mathematics like algebraic geometry, Algebraic Number Theory, Analytic Number Theory etc.

Course Syllabus:

- Euler's summation formula, Average order of arithmetic functions like divisor function, Mobius function, Sigma function, Euler's phi function etc.
- Distribution of prime numbers, Discussion of Prime Number Theorem, Tauberian Theorems.
- Dirichlet series, Multiplication of Dirichlet series, Euler products.
- Finite abelian groups and characters, Gauss sums associated with Dirichlet characters.
- Riemann zeta function and Dirichlet L-function, their zero free regions and functional equations. Dirichlet's Theorem for primes in an arithmetic progression.

Suggested Readings:

Introduction to Analytic number theory,
T. M. Apostol
Springer-Verlag, (1976).

Multiplicative Number Theory,
H. Davenport
Springer

Introduction to Analytic Number Theory
K. Chandrasekharan
Universities Press

Analytic Number Theory,
H. Iwaniec, E. Kowalski
American Mathematical Society Colloquium Publications 53, American Mathematical Society, (2004).

Problems in Analytic Number Theory,
M. R. Murty
Springer.

The Theory of Riemann Zeta function,
E. C. Titchmarsh, 2nd edition revised by D. R. Heath-Brown
Oxford Science Publications.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Advanced Complex Analysis-II

Course Code: MATH-DSE-401-11

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-11

Course Name: Advanced Complex Analysis-II

Brief Course Description:

Harmonic functions and Dirichlet problem for a disc, Harnack's theorem. Doubly periodic function, Weierstrass Elliptic function. Normal family in the space of meromorphic functions, Runge's theorem, Mittag-Leffler theorem. Definitions of the functions N(r,a), m(r,a) and T(r,f). Nevanlinna's first fundamental theorem and Nevanlinna's second fundamental theorem. Milloux theoremy. Nevanlinna's uniqueness theorem.

Prerequisite(s) and/or Note(s):

(1) Basic Complex Number and Complex Analysis
(2) Real Analysis and Calculus

Course Objectives:

Knowledge acquired:

(1) Mean value property, Poisson's integral formula, Dirichlet's problem for a disc
(2) Infinite product and its convergence
(3) Factorization theorems
(4) Poisson-Jensen formula, Nevanlinna's 1st fundamental theorem
(5) Uniqueness theorem of entire functions
(6) Value distribution of meromorphic functions, Milloux theorem

Skills gained:

(1) Relation between harmonic function and analytic function
(2) Generalization of fundamental theorem of algebra
(3) Compact subsets in the space of meromorphic functions
(4) Approximation of analytic function by sequence of rational functions

Competency developed:

(1) Characterizing harmonic functions.
(2) Representing entire functions as infinite product. Constructing maximum modulus like function for meromorphic functions
(3) Ability to compare the growth of meromorphic functions
(4) Characterization of doubly periodic entire functions in the plane
(5) Constructions of meromorphic function with prescribed zeros and singular parts

Course Syllabus:

- Harmonic functions, Mean-value property, Poisson's integral formula, Dirichlet problem for a disc, Harnack's theorem.
- Doubly periodic function, Weierstrass Elliptic function.
- Meromorphic functions. Spaces of meromorphic functions, Marty's theorem, Zalcman's lemma, Montel's theorem, Runge's theorem, Existence of meromorphic functions with prescribed zeros and singular parts, Mittag-Leffler theorem.

- Definitions of the functions N(r,a), m(r,a) and T(r,f). Nevanlinna's first fundamental theorem. Cartan's identity and convexity theorems. Order of growth, order of meromorphic function. Comparative growth of logM(r) and T(r).
- Nevanlinna's second fundamental theorem. Estimation of S(r) (Statement only). Nevanlinna's theorem on defiant functions. Nevanlinna's five-point uniqueness theorem, Milloux theorem.

Suggested Readings:

Meromorphic functions,
W. K. Hayman,
Oxford Universiy Press, 1964.

Theory of Functions of a Complex Variables, Vol. I & II,
A. I. Markusevich,
Printice-Hall, 1965.

Complex Analysis,
L. V. Ahlfors,
McGraw-Hill, 3rd Edn. 1979.

Theory of Analytic Functions,
H. Cartan,
Dover Publication, 1995.

Elements of the Theory of Elliptic and Associated Functions with Applications,
M. Dutta, L. Debnath,
World Press Pvt., 1965.

Value distribution theory,
L. Yang,
Springer-Verlag Berlin Heidelberg, 1993.

Complex Analysis,
T. W. Gamelin,
Springer, New York, 2001.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: C*-Algebra

Course Code: MATH-DSE-401-12

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-12

Course Name: C*-Algebra

Brief Course Description:

Density theorems, compact operators, existence of representation, spectrum of C*-algebra. Gelfand-Naimark theorem, Hilbert space operators, direct limits and tensor products, k-theory of C*-algebra.

Prerequisite(s) and/or Note(s): Functional analysis, advanced functional analysis, Ideas of density.

Course Objectives:

Knowledge acquired:

Students will be able to

(1) Introduce the special kind of algebra for C*-algebra

(2) Continue study of several topics like operators, Hilbert space, representation etc.

Skills gained:

(1) Study of fundamental concepts in algebra and analysis in the new setting

(2) Building a strong foundation for further studies and research in the related area

Competency developed:

One can have a clear brief idea of Banach algebra, representation, and special operators like Toeplitz operators

Course Syllabus:

- Operators and C*-algebras. Two density theorems. Ideal, quotients, and representations. C*-algebras of compact operators. Commutative C*-algebras and normal operators. Positive elements in C*-algebras. Quotients of a C*-algebra. Positive forms and representation: existence of representation of C*-algebras. The enveloping C*-algebra of an involutive Banach algebra. Ideals in C*-algebra. Spectrum of a C*-algebra.
- An arbitrary C*-algebra is isometrically *-isomorphic to a C*- algebra of bounded operators on a Hilbert space. von Neumann`s double commutant theorem and Kaplansky's density theorem. C-Algebras and Hilbert Space Operators. Ideals and Positive Functionals. Von Neumann Algebras. Representations of C-Algebras. Direct Limits and Tensor Products. K-Theory of C*-Algebras. Toeplitz operators.

Suggested Readings:

An invitation to C*-Algebra,
W. Arveson,
Springer-Verlag, New York, 1976.

C*-Algebras and operator theory,
Gerard J. Murphy,
Academic press, San-Diego, 2014.

C*-Algebra by Example,
K. R. Davidson,
G. J., American Mathematical Society, Providence Rhode Island, 2014.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV** ☑

Course Name: Advanced Algebra

Course Code: MATH-DSE-401-13

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-13

Course Name: Advanced Algebra

Brief Course Description:

Exact sequences, projective modules, injective modules, local ring, Noetherian and Artinian modules, composition series, Simple and Semi simple modules, Prime and semi prime ideal, Ring derivation.

Prerequisite(s) and/or Note(s): Students Should have the graduate level Abstract Algebra

Course Objectives:

Knowledge acquired:

(1) Exact sequences and their types

(2) Tensor product, direct sum and direct product of modules

(3) Projective modules, injective modules

(4) Noetherian, Artinian, simple and semi simple modules

(5) Nil radical, Jacobson radical

(6) Prime and semiprime ideal, m-system and n-system, prime radical

(7) Local ring, semi simple ring, Jacobson semi simple ring, regular ring, prime ring and semiprime ring

(8) Ring derivation

Skills gained:

(1) Ability to construct different new types of modules using tensor product, direct sum and direct product etc.

(2) Ability to characterize structures of different modules

(3) Identify prime (semiprime) rings in teams of m-system (n-system)

(4) Classify the commutativity of prime rings using derivations

Competency developed:

Helpful tool to study advanced Mathematics, particularly Commutative Algebra, Module Theory etc.

Course Syllabus:

- Exact sequences, short and split exact sequences, tensor product of modules, definition and existence, projective modules, injective modules, direct sum of projective modules, direct product of injective modules.
- Nil radical, Jacobson radical, Chinese remainder theorem, Rings and modules of fractions, local ring, characterizations of local ring, localization.
- Noetherian and Artinian modules, composition series, Simple and Semisimple modules. Semisimple ring, characterizations of semisimple ring, Jacobson semisimple ring, regular ring, idempotents in regular rings, lifting of idempotents.
- Prime and semiprime ideal, m-system and n-system, prime radical, prime rings, semiprime ring, ring derivation on prime and semiprime rings.

Suggested Readings:

Abstract Algebra (3e),
D. S. Dummit, R.M. Foote,
John Wiley and Sons (Asian reprint).

Basic Commutative Algebra,
B. Singh,
World Scientific, 2011.

Algebra,
W. A. Adkins, S. H. Weintraub,
Springer-Verlag, 1999.

Introduction to commutative Algebra,
M. F. Atiyah, I.G. MacDonald,
CRC Press, 2019.

Commutative Algebra,
D. Eisenbud,
Springer, USA, 2004.

Representations of finite groups,
C. Musili,
Hindustan Book Agency, India, 2011.

Representation theory of finite groups,
B. Steinberg,
Springer (India reprint 2015).

Advanced Modern Algebra,
J. J. Rotman,
Springer (Indian reprint 2016).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Modular Forms

Course Code: MATH-DSE-401-14

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-14

Course Name: Modular Forms

Brief Course Description:

MATH-DSE-401-14 deals with the introduction of modular forms and some related notions. In particular, the course will cover the full modular group $SL_2(\mathbb{Z})$ and its congruence subgroups, Eisenstein series, cusp forms, Hecke operators and Euler product for modular forms, theta functions and related topics.

Prerequisite(s) and/or Note(s):

(1) Undergraduate level Mathematics.

(2) Elementary number theory.

Course Objectives:

Knowledge acquired:

(1) The full modular group and Modular forms

(2) Eisenstein series, cusp forms

(3) Hecke operators and Euler product for modular forms

Skills gained:

(1) Ability to solve problems related to modular forms

(2) Use of Hecke operators while solving many problems

(3) Understanding of the Structure of the ring of modular forms

Competency Developed:

Basic preparation for research in various areas of mathematics like number theory, combinatorics, computer science etc.

Course Syllabus:

- The full modular group $SL_2(\mathbb{Z})$ and its congruence subgroups, the upper half-plane H, Action of groups on H, Fundamental domains
- Modular forms for $SL_2(\mathbb{Z})$, modular forms for congruence subgroups, Eisenstein series, cusp forms. Differential operators. Structure of the ring of modular forms
- Hecke operators and Euler product for modular forms. The L-function of a modular form, functional equations. Theta functions, transformation formula, sums of four squares

Suggested Readings:

Introduction to Modular Forms,
S. Lang
Springer-Verlag.

A Course in Arithmetic, Graduate Texts in Mathematics 7,
J. P. Serre
Springer-Verlag.

Introduction to Elliptic Curves and Modular Forms,

N. Koblitz
Graduate Texts in Mathematics 97, Springer-Verlag.

The 1-2-3 of Modular Forms,
J. H. Bruinier, G. van der Geer, G. Harder, D. Zagier
Universitext, Springer-Verlag.

A First Course in Modular Forms, Graduate Texts in Mathematics 228,
F. Diamond, J. Shurman
Springer-Verlag.

Problems in the theory of modular forms,
M. Ram Murty
Hindustan book agency.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV** ☑

Course Name: p-adic analysis

Course Code: MATH-DSE-401-15

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-15

Course Name: p-adic Analysis

Brief Course Description:

Non-Archimedean norm, p-adic integers, Hensel's lemma, Ostrowski's theorem.
Topology, countability, convergence properties in $\mathbb{Q}p$, relation between Cantor sets and $\mathbb{Q}p$.

Prerequisite(s) and/or Note(s): Completions, Archimedean field, decimal and binary representation, countability Cantor set and Infinite series.

Course Objectives:

Knowledge acquired:

(1) Study of non-Archimedean normed field

(2) idea of field of p-adic numbers

(3) consequences of Hensel's lemma

Skills gained:

(1) construction of non-Archimedean norms

(2) Study of p-adic numbers

Competency developed:

(1) Arithmetical operation in $\mathbb{Q}p$

(2) Relevance of Cantor's set

(3) p-adic power series

Course Syllabus:

- Completion from $\mathbb{Q}$ to $\mathbb{R}$, normed fields, non-Archimedean norm; basic properties, construction of the completion of a normed field, the field of p-adic numbers $\mathbb{Q}_p$, arithmetical operations in $\mathbb{Q}_p$, p-adic integers, p-adic rational numbers; a necessary and sufficient condition for x in $\mathbb{Q}_p$ to be rational, uncountability of the set of p-adic integers, Hensel's lemma and congruences, p-adic norm on $\mathbb{Q}$; Ostrowski's theorem.
- Topology of $\mathbb{Q}_p$, spheres and balls in $\mathbb{Q}_p$, countability of set of all balls in $\mathbb{Q}_p$, local compactness and totally disconnectedness of $\mathbb{Q}_p$.
- Cantor sets, the set $\mathbb{Z}_2$ of 2-adic integers is homeomorphic to Cantor set C, basic convergence properties of sequences and series in $\mathbb{Q}_p$, p-adic power series; its convergence.

Suggested Readings:

p-adic analysis compared with real,
S. Katok,
American Mathematical Society (2007).

p-adic Numbers: An Introduction,
F. Q. Gouvˆea,
2nd edition, Springer-Verlag (1997).

The Elements of Cantor Sets: With Applications,
R. W. Vallin,

Wiley.

A course in p-adic analysis,
A. M. Robert,
Springer-Verlag, (2000).

Introduction to p-adic numbers and valuation theory
G. Bachman,
Academic Press (1964).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Complex Differential Equations

Course Code: MATH-DSE-401-16

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☑

Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-DSE-401-16

Course Name: Complex Differential Equations

Brief Course Description:

Complex polynomial, Cannonical product, Wronskian determinant, Basic of Nevanlinna theory, Proximity function of the logarithmic derivative.
Linear differential equation: basic results, zero distribution in the second order linear differential equations, Schwarzian derivative.
Higher order linear differential equations, non-homogeneous linear differential equations.
Non-linear differential equations, Riccati differnatial equations, Painleve differential equations, Schwarzian equations.
First and second algebraic differential equations.

Prerequisite(s) and/or Note(s):

(1) Graduate level mathematics.
(2) Note(s): Syllabus changes yearly and may be modified during the term itself, depending on the circumstances. However, students will be evaluated only on the basis of topics covered in the course.

Course Objectives:

Knowledge acquired:

(1) Complex polynomial, Cannonical product and their properties
(2) Proximity function of the logarithmic derivative
(3) Distribution of solutions of Linear and Non-linear differential equations
(4) Algebraic differential equations

Skills gained:

(1) Basic concept of the complex differential equations from the algebraic point of view
(2) How the Nevanlinna theory applied to get insight into the properties of solutions of complex differential equations
(3) Analyze the distributions of zeros of solutions of linear and non-linear differential equations
(4) To compile an exposition which gives a reasonably access to the value distribution theory of solutions of Differential equations
(5) Concept of algebraic differential equations

Competency developed:

The students would gain

(1) fundamental idea about local and global theory of complex differential equations.
(2) understanding about the value distribution of solutions of complex differential equations

Course Syllabus:

- Complex polynomial, Cannonical product, Wronskian determinant, Basic of Nevanlinna theory, Proximity function of the logarithmic derivative
- Linear differential equation: basic results, zero distribution in the second order linear differential equations, Schwarzian derivative

- Higher order linear differential equations, non-homogeneous linear differential equations.
- Non-linear differential equations, Riccati differnatial equations, Painleve differential equations, Schwarzian equations
- First and second algebraic differential equations

Suggested Readings:

Nevanlinna Theory and complex differential equations,
I Laine,
Walter de Gruyter, New York, 1993.

Ordinary differential equations in the complex domain,
E. Hille,
Wiley, New York-London-Sydney, 1976.

First order algebraic differential equations,
M. Matxida,
Springer, 1980.

Periodic differential equations,
F. M. Arscott,
New York, 1964.

Meromorphic functions,
W.K. Hayman,
Clarendon press, Oxford, 1964.

Schwarzian derivative and second order differential equations,
Y.M. Chiang,
London, 1991.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name:

Course Code: MATH-SEC-401

Course Credit: 2

Marks Allotted: Theoretical/Practical: 40 Continuing Evaluation: 10

Course Type (tick the correct alternatives):

- Core ☐
- Department Specific Elective ☐
- Generic Elective ☐

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number:

Course Code: MATH-SEC-401

Course Name:

Brief Course Description:

Prerequisite(s) and/or Note(s):

Course Objective:

Knowledge acquired:

Skills gained:

Competency developed:

Course Syllabus:

Suggested Readings:

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Discrete Mathematics, Data Structure and Algorithms

Course Code: MATH-GE-401-01

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☑

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-401- 01

Course Name: Discrete Mathematics, Data Structure and Algorithms

Brief Course Description:

An overview of data structure concepts, arrays, stack, queues, trees, and graphs. Discussion of various implementations of these data objects, programming styles, and run-time representations. Course also examines algorithms for sorting, searching and some graph algorithms. Algorithm analysis and efficient code design is discussed.

Logic: Propositions and Logical operators, Equivalence and Implications of statements, Tautology, Conditional conclusions, quantifiers, argument, theory of inference.
Combinatorics: The basic problem of Combinatorics-Counting, Generalized Permutations and Combinations, Pigeonhole principle, Recurrence Relations, Generating functions, Solving recurrence relations using generating functions, Difference equations, Principle of Inclusion–Exclusion.

Lattice and Boolean algebra: Partially ordered sets, Lattices, Complements, Boolean algebra, and Boolean Expressions, Basic laws of Boolean Algebra CNF, DNF, and Expression of Boolean function by algebraic method.

Prerequisite(s) and/or Note(s): Knowledge of programming languages, basic of mathematics, organising and problem solving ability.

Course Objectives:

Knowledge acquired:

(1) Understanding of fundamental Data Structures including linked-lists, trees, binary search trees, AVL trees, stacks, queues, priority queues, and hash-tables and skip lists

(2) Understanding of fundamental abstract data types which can include: Maps, Sets and Vectors

(3) Understanding of basic algorithmic complexity

(4) To understand importance of data structures in context of writing efficient programs

(5) Application to real life problems such as network theory, data structure, optimization etc.

(6) Basic logical concepts, analysing arguments, quantification theory

Skills gained:

(1) Solve problems using data structures such as linear lists, stacks, queues, hash tables, binary trees, heaps, tournament trees, binary search trees, and graphs and writing programs for these solutions

(2) Solve problems using algorithm design methods such as the greedy method, divide and conquer, dynamic programming, backtracking, and branch and bound and writing programs for these solutions

(3) Efficiency in handling with discrete structures

(4) Efficiency in solving concrete combinatorial problems whose presence is ubiquitous in science and engineering

Competency developed:

(1) Ability to program data structures and use them in implementations of abstract data types

(2) Ability to devise novel solutions to small-scale programming challenges involving data structures and recursion

(3) Ability to estimate the algorithmic complexity of simple, non-recursive programs

(4) Ability to perform simple inductive proofs and proofs by contradiction and reason about program correctness and invariants

(5) Ability to sensibly select appropriate data structures and algorithms for problems and to justify that choice

(6) Ability to apply combinatorial intuitions in network theory, data structure and various other fields of science

Course Syllabus:

- Propositions and Logical operators, Equivalence and Implications of statements, Tautologies of statements, Direct proofs, Conditional conclusions, Indirect proofs, The existential and universal quantifiers, Predicate calculus including theory of inference.
- The basic problem of Combinatorics-Counting, Generalized Permutations and Combinations, Pigeonhole principle, Binomial Coefficients and Identities, Recurrence Relations, Applications of Recurrence Relations, Solving Linear Recurrence Relations, Generating functions, definition with examples, Solving recurrence relations using generating functions, exponential generating functions. Difference equations, Principle of Inclusion–Exclusion, Applications of Inclusion–Exclusion. Modeling with recurrence relations with examples of Fibonacci numbers and the tower of Hanoi problem.
- Partially ordered sets, Lattices, Complete Lattices, Distributive lattices, Complements, Boolean Algebra, Boolean Expressions, Basic laws of Boolean Algebra CNF, DNF, Expression of Boolean function by algebraic method, Application to switching circuits
- Stack and queues, linked list, Direct address tables, Indexing, hash tables, open addressing, trees, Binary search tree, height-balanced tree, Red-black tree, B-tree.
- Basic concepts of algorithms, Complexity, Asymptotic notations, Trees: Binary tree, Binary Search Tree, Tree traversals.
- Heap as a data structure. Basic sorting algorithms: selection sort, insertion sort.
- Greedy algorithms: Coin change problem, activity selection, Minimum Spanning Tree, Single source shortest path, knapsack problem.
- Divide â and â Conquer technique: Merge sort, quicksort. Solving Recurrence relations.
- Dynamic programming: matrix chain multiplication, all pair shortest path algorithm. Graph algorithms: Warshall algorithm, Depth First Search, Breadth-First Search. Branch and Bound technique, Backtracking. NP-completeness.

Suggested Readings

Data Structures with C,
Seymour Lipschutz,
McGraw Hill, 2014.

Data Structures, 2nd ed.,
R.F.Gilberg, B.A.Forouzan,
Thomson India, 2005.

Data structures and Algorithms,
A.V.Aho, J.E Hopcroft , J.D.Ullman,
Pearson Education, 2003

Data Structures and Algorithm Analysis in C, 2nd ed.,
Mark Allen Weiss,
Pearson Education, 2015

Data Structures Using C, 1st ed.,
Reema Thareja,
Oxford Higher Education, 2011

Introduction to Algorithms 3rd ed.,
Thomas H Cormen, Charles E Leiserson, Ronald L Revest, Clifford Stein,
The MIT Press Cambridge, 201

A textbook of discrete mathematics,
Swapan Kumar Sarkar,
9th edition, S.Chand Publishing, 2016.

Discrete mathematics for Computer Scientists and Mathematicians,
J. L. Mott, A. Kandel, T. P. Baker,
2nd edition, Prentice Hall (India), 1999.

Discrete mathematical structures,
B. Kolman, R. C. Busby, S. Ross,
3rd edition, Prentice Hall (India), 1999.

Discrete Mathematics: Theory and Applications (Revised Edition),
D. S. Malik and M. K. Sen,
Cengage Learning India, 2012.

Elements of Discrete Mathematics,
C. L. Liu,
2nd edition, McGraw Hill, Computer Science series, 1986.

Introductory Combinatorics,
R. A. Brualdi,
Prentice Hall (India).

Discrete mathematics with algorithms,
M. O. Albertson, J. P. Hutchinson,
John Wiley and Sons, 1988.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Mathematical Physics

Course Code: MATH-GE-401-02

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

- Core ☐
- Department Specific Elective ☐
- **Generic Elective ☑**

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

- Minor (up to 15%) ☐
- Moderate (>15% and up to 50%) ☐
- Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-401-02

Course Name: Mathematical Physics

Brief Course Description:

The aim of this course is to provide a solid mathematical foundation for the budding Physicist eager to climb the ladder of self-learning. This course is designed to cater to an undergraduate student who excitedly embarks on a study of Physics, but is obstructed by the mathematics which appears so forbidding. The approach we will follow is one of showing many examples, and weaving the theory around examples.

Prerequisite(s) and/or Note(s): Basic algebra, Trigonometry, and basic Probability

Course Objectives:

Knowledge acquired:

(1) Develop knowledge in mathematical physics and related theorems

(2) Understand the axiomatic structure of mathematics

(3) Understand the special functions and its role in solutions of physics' equations

(4) Understand beta and gamma functions as very important special functions

(5) Understand and apply complex analysis techniques

Skills gained:

(1) Develop expertise in mathematical techniques and the mathematics behind it

(2) Enhance problem solving skills and efficiency with necessary mathematics

(3) Understand the probability and the probability distribution in describing the uncertainty in physics

(4) Understand and develop the solution methods for integral equation

(5) Understand and develop the Dirac delta function as a generalized function

Competency developed:

(1) Enable students to formulate, interpret and draw logical conclusions from mathematical solutions

(2) Appreciate untraceable connection between mathematics and physics

Course Syllabus:

- Definition of a group, subgroup, class, Lagrange's theorem, invariant subgroup, Homomorphism and isomorphism between two groups. Representation of a group, unitary representations, reducible and irreducible representations Schur's lemmas, orthogonality theorem, character table, reduction of Kronecker product of representations, criterion for irreducibility of a representation.
- Infinitesimal generators, Lie algebra; Rotation group, representations of the Lie algebra of the rotation group, representation of the rotation group, D-matrices and their basic properties. Addition of two angular momenta and C.G. coefficients, Wigner-Eckart theorem.
- Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors.

Associated tensors. Raising and lowering of indices. The Christoffel symbols and their transformation laws. Covariant derivative of tensors.

- Asymptotic expansion of functions, power series as asymptotic series, Asymptotic forms for large and small variables. Uniqueness properties and Operations. Asymptotic expansions of integrals; Method of integration by parts (include examples where the method fails), Laplace method and Watson's lemma, method of stationary phase and steepest descent.
- Parameter and co-ordinate perturbations. Regular perturbation solution of first and second order differential equations involving constant and variable coefficients. Include Duffings equation, Vanderpol oscillator, small Reynolds number flow. Singular perturbation problems, Matched asymptotic expansions, simple examples. Linear equation with variable coefficients and nonlinear BVP's. Problems involving Boundary layers. Poincare–Lindstedt method periodic solution. WKB method, turning points, zeroth order Bessel function for large arguments, solution about irregular singular points.

Suggested Readings:

Perturbation Methods,
A. H. Nayfeh
John Wiley & sons New York.

Real analysis with introduction to wavelets and applications,
Don Hong, J. Wang and R. Gardner,
Academic Press Elsevier.

Mathematical Methods for Physicists – A Comprehensive Guide (7th edition),
G. Arfken and H. J. Weber,
Academic press.

Mathematical Methods of Physics,
J. Mathews and R. I. Walker,
Benjamin.

Mathematics for Physicists,
P. Dennery and A. Krzywicki,
Harper and Row.

Introduction to Mathematical Physics,
C. Harper
California State University, Hayward.

Mathematical Physics,
B. D. Gupta,
Vikas Publishing House Pvt. Ltd.

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Fundamentals of Biomathematics

Course Code: MATH-GE-401-03

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☑

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-401-03

Course Name: Fundamentals of Biomathematics

Brief Course Description:

An increasing number of problems in the biological sciences are being solved using sophisticated mathematical and computational tools. The biomathematics degree blends mathematics, biology, and computer science in preparation for continued graduate studies and for careers in the quantitative life sciences. The degree's mission is to provide a world class undergraduate education in applied mathematics used in support of the life sciences.

Prerequisite(s) and/or Note(s): Calculus and Differential Equations.

Course Objectives:

Knowledge acquired:

(1) Application of mathematical modeling in the analysis of biological systems including populations of molecules, cells, and organisms

(2) Apply and extend classical models in mathematical biology

(3) Use sophisticated mathematical techniques in the analysis of mathematical models in biology

(4) Perform appropriate data manipulations, and graphically display model output and data clearly and accurately

(5) Formulate discrete and differential equation models that represent a range of biological problems, including identifying assumptions that are appropriate for the problem to be solved

Skills gained:

(1) Construct mathematical models for biological systems

(2) The use of computers to assist them in studying mathematical functions and carrying out statistical tests

(3) Interpret model and data output in terms of the original biological problem, and use results to direct a follow-up experiment

(4) Choose and apply computational tools to perform parameter estimation and to solve discrete and differential equation models

Competency developed:

(1) Develop the ability to explain mathematical results in language understandable by biologists

(2) Solve mathematically and interpret biologically simple problems involving one- and two-species ecosystems, epidemics, and biochemical reactions

(3) Explore mathematical problems in the medical and biological sciences; to give mathematics students the opportunity to gain familiarity with the vocabulary of biology

Course Syllabus:

- Population Growth, Growth in Chemostat, Product formation due to Microbial Action, Competition for Growth Rate Limiting Substrate in a Chemostat, Competition for One Rate Limiting Substrate, Commensalism, Mutualism, Predation, Mutation.
- Logistic model, Logistic model with time delay, Stochastic model on population growth, Discrete-Time Discrete, Continuous-Time Discrete, Continuous-Time Continuous-Age Scale Population Model, Reconciliation of above models.
- Simple Pray-Predator model, Pray-Predator model with time delay.
- Growth of Population with Harvesting, Optimal Utilization of Renewable Resources, Optimization for a model with linear growth and Harvesting functions, Quadratic cost function, Optimal control of fisheries, Optimal Harvesting, Optimal utilization of forest.
- Deterministic models without removal, General deterministic model: with removal, with removal and immigration, Control of an epidemic, Stochastic epidemic models.
- Basic models for inheritance, Basic models for inheritance of generic characteristics, models of genetic improvement, genetic inbreeding.
- Basic equations and solutions, special cases, Transfer coefficients, Compartment volumes, Mathematics techniques used in compartment analysis, Stochastic compartment models.
- Basic concept of fluid dynamics, Cardiovascular systems, blood flow, Newtonian and non-Newtonian fluid flows, Pulsatile flows, Blood flow through arteries with stenosis, peristaltic flows in tubes and channels, gas exchange and air flows in lungs, flow in renal tubules, lubrication in human joints.
- Diffusion equations, Hemodialyzer, oxygen diffusion through living tissues, absorption and diffusion of γ-globulin by lung tissue, diffusion reaction systems.

Suggested Readings:

Mathematical Biology: I. An Introduction, Third Edition,
J. D. Murray,
Springer-Verlag (2002).

Mathematical Biology II: Spatial Models and Biomedical Applications Third Edition,
J. D. Murray,
Springer-Verlag (2003).

Mathematical Models in Biology and Medicine,
J. N. Kapur,
East West Press Pvt Ltd, (1985)

Mathematical Models,
R. Habermann,
Prentice Hall, (1977).

An Introduction to Mathematical Ecology,
E. C. Pielou,
Wiley, New York, (1977).

Foundation of Mathematical Biology (vol. I& II),
R. Rosen,
Academic Press, (1972)

The Physics of Pulsatile Flow,
M. Zamir, E L Ritman,
Springer, (2000).

Blood Flow in Arteries,
D. A. MacDonald,
The Williams and Wilkins Company, Baltimore (1974).

Biofluid Mechanics,
J. N. Mazumdar,
World Scientific (2015).

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Introduction to Mathematical Finance

Course Code: MATH-GE-401-04

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☑

Is the course focused on employability / entrepreneurship? YES ☐ NO ☐

Is the course focused on imparting life skill? **YES** ☑ NO ☐

Is the course based on Activity ? YES ☐ **NO** ☑

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-401-04

Course Name: Introduction to Mathematical Finance

Brief Course Description:

This course deals with Investments and Markets, The Basic Theory of Interest, Capital Budgeting, Dynamical Cash flow Process, Optimal Management, Asset Return, Portfolio Mean and Variance, Capital Market, The Pricing Model, Investment Implications, Stock market Basic, Assets, Financial regulator and Intermediaries, The IPO Market and 99The Trading terminal.

Prerequisite(s) and/or Note(s): Background in basics of probability theory

Course Objectives:

Knowledge acquired:

(1) Provide an introductory on Financial Mathematics

(2) Understand Asset Pricing and Stochastic Process under Finance

(3) Know the techniques of Black Scholes model, arbitrage, option values, European Options and American Option in Problem in financial Engineering

(4) Gain knowledge of Brownian Motion and Binomial Methods in Problems involving the financial Engineering

Skills gained:

(1) Apply the concept of Stochastic differential equations in problems of Financial Engineering

(2) Develop skills in practical, analytical problem-solving in some parts of Mathematical Finance

(3) Gain familiarity in the knowledge Stock Market, Investment and securities, Stock return, Risk, Option and futures

Competency developed:

(1) Gain familiarity in the knowledge of Asset Pricing and its properties, Markov

(2) property and Martingale property its applications in the problems involving

(3) Mathematical Finance

(4) Gain the knowledge of Black Scholes equation, Arbitrage, European options, and

(5) American option in Mathematical Finance

(6) Gain the knowledge of Brownian motion, Limit of scaled random walks, and Binomial methods in the problems involving Financial Engineering.

(7) Acquire the knowledge and developing Mathematical Finance

Course Syllabus:

- Cash Flows, Investments and Markets, The Basic Theory of Interest, Principal and Interest, Present Value, Present and Future Values of Streams, Internal rate of Return, Evaluation Criteria, Fixed-Income Securities, The Market for Future Cash, Bond Details, The Term Structure of Interest Rates, Capital Budgeting, Dynamical Cash flow Process.

- Optimal Management, Asset Return, Portfolio Mean and Variance, Risk Free Asset, Capital Market, The Pricing Model, Investment Implications, CAPM as a Pricing Formula, Derivative Securities, Forwards, Futures and Swaps, Stock market Basic, Assets, Financial regulator and Intermediaries, The IPO Market, The Trading terminal.

Suggested Readings:

Investment Science
D. G. Luenberger
Oxford University Press, 2009.

An Introduction to Mathematical Finance
S. M. Ross
Cambridge University Press, 1999

Mathematical Finance Theory, Modeling, Implementation
C. Fries
Wiley, 2007

Department Name: Mathematics

Program Name: PG in Mathematics

Program Code:

Semester: Semester I ☐ Semester II ☐ Semester III ☐ **Semester IV ☑**

Course Name: Mathematical Cryptography

Course Code: MATH-GE-401-05

Course Credit: 4

Marks Allotted: Theoretical/Practical: 80 Continuing Evaluation: 20

Course Type (tick the correct alternatives):

Core ☐

Department Specific Elective ☐

Generic Elective ☑

Is the course focused on employability / entrepreneurship? **YES ☑** NO ☐

Is the course focused on imparting life skill? **YES ☑** NO ☐

Is the course based on Activity ? YES ☐ **NO ☑**

Percentage of change in syllabus (applicable in case of change in syllabus only)

Minor (up to 15%) ☐

Moderate (>15% and up to 50%) ☐

Major (> 50%) ☐

Summary of changes

PG BOS Meeting Reference Number: Date:

Course Code: MATH-GE-401-05

Course Name: Mathematical Cryptography

Brief Course Description:

Introduction to Cryptography, Classical Cryptography, Data Encryption Standard (DES), Advanced Encryption System (AES), Introduction to Public Key Cryptosystem, RSA Cryptosystem, Message Authentication, Digital Signature, Cryptographic Hash Function, Secure Hash Algorithm (SHA), Digital Signature Standard (DSS), Cryptanalysis, Differential Cryptanalysis, Linear Cryptanalysis, Shamir's Secret Sharing and BE, Identity Based Encryption (IBE), Attribute Based Encryption (ABE), Implementation Attacks, The Secure Sockets Layer, Pretty Good Privacy.

Prerequisite(s) and/or Note(s):

Algebra with special emphasis on Abstract and Linear Algebra with a little knowledge on computer (How does it work?, little bit about programming etc.)

Course Objectives:

Knowledge acquired:

1) One can understand various public key cryptosystem such as Diffie-Hellman key exchange, Knapsack cryptosystem, RSA, etc.
2) One can gather knowledge about the significance of Authentication/Digital Signatures, Secure Network Communications etc.

Skills gained:

1) Describe the basic issues around finding large prime numbers and factoring large composite numbers, including various techniques for both. Explain the significance of these problems to public-key cryptography.
2) One can able to define elliptic curves and explain the group law on these curves, both geometrically and formulaically. Explain how elliptic curves are used in certain cryptographic algorithms.

Competency gained:

On completion of this course, the students (on average) will be able to analyze and design clasical encryption techniques and block Ciphers.

Course Syllabus:

- Introduction to Cryptography, Classical Cryptography, Cryptanalysis on Cipher, Play Fair Cipher.
- Block Cipher, Data Encryption Standard (DES), Triple DES and Modes of Operation, Stream Cipher, Pseudorandom Sequence, Advanced Encryption System (AES).
- Introduction to Public Key Cryptosystem, Diffie-Hellman Key Exchange, Knapsack Cryptosystem, RSA Cryptosystem, Primarily Testing, Elgamal Cryptosystem, Elliptic Curve, Elliptic Curve Modulo a Prime, Generalized Elgamal Public Key, Rabin Cryptosystem,
- Message Authentication, Digital Signature, Key Management, Key Exchange,
- Hash Function, Universal Hashing, Cryptographic Hash Function, Secure Hash Algorithm (SHA), Digital Signature Standard (DSS).
- Cryptanalysis, Time-Memory Trade of Attack, Differential Cryptanalysis, Linear Cryptanalysis, Cryptanalysis On Stream Cipher, Modern Stream Ciphers,
- Shamir's Secret Sharing and BE, Identity Based Encryption (IBE), Attribute Based Encryption (ABE), Functional Encryption, Solving discrete problem, Implementation Attacks, The Secure Sockets Layer, Pretty Good Privacy.

Suggested Readings:

A Course in Number Theory,
Neal Koblitz,
Springer.

Prime Numbers; A Computational Perspective,
Richard Crandall & Carl Pomerance,
Springer.

The Little Book of Bigger Primes,
Paulo Ribenbolm,
Springer.

Cryptography and Computational Number Theory,
Carl Pomerance,
Springer.

An Introduction to Mathematical Cryptography,
J. H. Silverman, Jill Pipher & Jeffrey Hoffstein,
Springer.

Cryptography and Network Security,
Behrouz A Forouzan & Debdeep Mukhopodhyay,
Tata McGraw Hill.