University of Lucknow
M.A. /M.Sc. Mathematics Programme
Regulations 2020

1. **Applicability**

These regulations shall apply to the M.A. / M.Sc. Mathematics Programme from the session 2020-21.

2. **Minimum Eligibility for admission**

A three/four-year Bachelor's degree or equivalent with Mathematics in the final year awarded by a University or Institute established as per law and recognised as equivalent by this University with minimum marks : General /OBC 45%, SC/ST 40% in aggregate or equivalent grade, shall constitute the minimum requirement for admission to the M.A/M.Sc. Mathematics Programme.

3. Programme Outcomes

i) To provide a comprehensive curriculum to groom the students for quality scientific manpower.

ii) To prepare the students with an ability to identify and analyse complex problems reaching substantiated conclusions using principles of Mathematics integrated with other streams of science.

iii) To inculcate the curiosity for mathematical reasoning and assimilate complex mathematical ideas, arguments and develop abstract mathematical thinking as part of preparation for pursuing research studies in mathematics and related fields.

iv) To develop the ability to design and apply knowledge of mathematics to real life situations for solution of problems in the domain of science, engineering and data sciences particularly as numerical analyst in computer system design, operation research, software programming etc.

v) To equip the students with an ability to demonstrate problem-solving skills and apply them independently to problems in pure and applied mathematics

vi) To groom the students with an ability to communicate effectively the mathematical inferences with the scientific community and with the society at large by being able to comprehend and write effective reports and make effective presentations.

vii) To enable the students to display the above competencies by successfully cracking competitive examinations for careers in administration, teaching, research, business and industry.

4. Specific Programme Outcomes

i. Understand the nature of abstract mathematics and explore the concepts in further details.
ii. Apply the knowledge of mathematical concepts in interdisciplinary fields.
iii. Read, analyze and comprehend mathematical ideas with clarity, coherence and write logical arguments to prove concepts.
iv. Enhance mathematical skills and understand the fundamental concepts of pure and applied mathematics.
v. Solve problems in the advanced areas of real analysis, complex analysis, mathematical modeling, integral and differential equations, linear algebra, topology, approximation theory, fluid mechanics, differentiable manifolds and discrete mathematics.
vi. Model the real-world problems in to mathematical equations and draw the inferences by finding appropriate solutions.
vii. Identify challenging problems in mathematics and find appropriate solutions to pursue research in challenging areas of pure and applied mathematics.
viii. Communicate both written and verbally and design documentation related to mathematical research and literature, make effective presentations.
ix. Explore ideas of mathematics for propagation of knowledge and popularization of mathematics in society.
x. Qualify National and International level tests like NET/GATE/GRE etc.

5. Programme Structure

The programme structure of the Master in Mathematics Programme shall be as under:

Course No.	Name of the Course	Credits	Remark
	Semester I		
MACC-101	Topology I	**04**	Core Course
MACC-102	Advanced Algebra	**04**	Core Course
MACC-103	Differential Geometry and Manifolds	**04**	Core Course
MACC-104	Integral & Partial Differential Equations	**04**	Core Course
MACC-105	Fluid Mechanics I	**04**	Core Course
MAVC-101	Measure Theory & Integration	**04**	Value Added Course (Credited)
	Semester Total	**24**	
	Semester II		
MACC-201	Topology II	**04**	Core Course
MACC-202	Module Theory	**04**	Core Course
MACC-203	Riemannian Manifolds, Lie Algebra & Bundle Theory	**04**	Core Course
MACC-204	Ordinary Differential Equations	**04**	Core Course
MACC-205	Complex Analysis	**04**	Core Course
MACC-206	Fluid Mechanics II	**04**	Core Course
MAVNC-201	Mathematical Modeling	**00**	Value Added Course (Non Credited)
	Semester Total	**24**	
	Semester III		
MACC-301	Functional Analysis	**04**	Core Course/MOOC
MACC-302	Structures on almost Complex Manifolds	**04**	Core Course
MAEL-301A	Advanced Ordinary Differential Equations	**04**	Elective
MAEL-301B	Cryptography		
MAEL-302A	Discrete Mathematics	**04**	Elective
MAEL-302B	Approximation Theory		
MAIN-301	Summer Internship	**04**	Summer Internship
MAIER-301A	Mathematics in Computer Designing	**04**	Interdepartmental course
MAIER-301B	Astronomy & Astrophysics		
	Semester Total	**24**	
	Semester IV		
MACC-401	Advanced Linear Algebra	**04**	Core Course
MAEL-401A	Advanced Partial Differential Equations	**04**	Elective
MAEL-401B	Almost Contact Manifolds & F-Structure Manifolds		
MAEL-402A	Graph Theory	**04**	Elective
MAEL-402B	Wavelet Theory		
MAMT-401	Master Thesis	**08**	Master Thesis
MAIRA-401A	Mathematical Biology	**04**	Intradepartmental Course
MAIRA-401B	Astrobiology		
	Semester Total	**24**	
	GRAND TOTAL	**96**	

MA- Mathematics; MACC- Core Course; MAVC- Value Added Course (Credited); MAVNC- Value Added Course (Non Credited); MAEL- Elective;
MAIER- Interdepartmental Course; MAIRA- Intradepartmental Course

6. Course Outlines

SEMESTER –I

MACC-101: Topology I

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Define and illustrate the concept of topological spaces and continuous functions,
2. Illustrate the concept of limit point, dense sets, interior, exterior, boundary points.
3. Identify and understand bases, sub-bases and different type of spaces like Lindeloff, Separable, and their properties.

Unit I

Countable and uncountable sets, Infinite sets and the axiom of choice, Cardinal numbers and its arithmetic, Schroeder-Bernstein theorem, Cantor's Theorem, Cantor's Sets, Cantor's continuum hypothesis, Zorn Lemma, Well ordering principle.

Unit II

Definition and examples of topological spaces, Types of topologies (Box, Order etc.), Closed sets, Closure, Dense subsets, Neighbourhoods, Interior, exterior and boundary, Accumulation points and derived sets.

Unit III

Subspaces and relative topology. Alternative methods of defining a topology in terms of Kuratoivski closure axioms, interior operator and neighbourhood. systems, Continuous functions and homeomorphism.

Unit IV

Bases and Sub bases, First and Second countable spaces, Lindeloff spaces, Lindeloff theorem, Seperable spaces.

Unit V

Separation axioms T_0, T_1, T_2 , their characterization and basic properties, nets and Filter, Topology and Convergence of nets, Hausdorffness and nets, Filter, types of filters, filter base, Filter and their convergence.

Books Recommended:

1. G.F. Simmons: Introduction to Topology and Modern Analysis, Mc-Graw Hill Int. Book Company
2. J.L. Kelley: General Topology. Van Nostrand. Reinhold Co, New York 1995
3. J.R.Munkres: Topology - A first course, Prentice hall India Pvt. Ltd.

MACC-102: Advanced Algebra

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Give the structure of an abelian group of a given order
2. Construct the splitting field extension of a given polynomial
3. Understand the interplay of group theory and field theory
4. Determine the minimal polynomial of an algebraic element

Unit I

Series of groups, Schreier theorem, Jordan Holder theorem, solvable groups, Nilpotent groups, Insolvability of Sn for n>5,

Unit II

Finite Abelian groups, primary decomposition theorem, basis theorem, fundamental theorem of finite Abelian group, elementary divisors and invariant factors,

Unit III

Field extensions: finite extension, finitely generated extension, algebraic extension, simple extension, transcendental extension, finite field.

Unit IV

Splitting field, algebraically closed field, normal extension, separable extension, primitive element theorem.

Unit V

Galois theory- Galois group, Galois extension, Fundamental theorem of Galois theory, Artin's theorem, Fundamental theorem of algebra (Algebraic Proof)

Books Recommended :

1. S. Lang: Algebra, Addison Wesley.
2. V. Sahai & V. Bist: Algebra, Fourth Edition, Narosa.
3. J.B. Fraleigh: A first course in Abstract algebra, Narosa

MACC -103: Differential Geometry of Manifolds

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Elaborate the concept of differentiable manifolds and their examples
2. Clarify the concepts of vector fields, tangent vectors & tangent spaces in a manifold
3. Apply various concepts of differential calculus to the settings of abstract set called manifold.
4. Use Riemannian metric on a given manifold to find the various types of curvatures with emphasis on the surface/ type of manifold
5. Bring out different connections on Riemannian manifold and it's properties
6. Calculate curvature tensor & tensors of respective connections

Unit I

Definition and examples of differentiable manifolds, Tangent vectors, Tangent Spaces, Vector fields and their examples, Jacobian map.

Unit II

Immersions and submersions, Diffeomorphism and their examples, Curve in a manifold, Integral curves and their examples, Distributions, Hypersurface of R^n , Submanifolds.

Unit III

Standard connection on R^n , Covariant derivative, Sphere map, Weerigarten map, Gauss equation, the Gauss curvature equation and Coddazi-Mainardi equations.

Unit IV

Invariant view point cortan view point coordinate view point, Difference Tensor of two connections, Torsion and curvature tensors.

Unit V

Riemannian Manifolds, Length and distance in Riemannian manifolds, Riemanian connection and curvature, Curves in Riemannian manifolds, Submanifolds of Riemannian manifolds.

Books Recommended:

1. N.J. Hicks: Notes on Differential Geometry, D. Van Nostrand, 1965.
2. Y. Matsushima: Differentiable Manifolds, Marcel Dekker, INC. New York, 1972.
3. U. C. De., A. A. Shaikh: Differential Geometry of Manifolds, Narosa Publishing House.

MACC-104: Integral & Partial Differential Equations

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Describe different types of Linear integral equations and partial differential equations for the impart knowledge of formulation of practical problems of applied mathematics.
2. Understand the theoretical basic behavior of different types of arising problems such as Fredholm, Volterra, Singular, Hilbert and Cauchy integral equations.
3. Explain the foundations of various problems related to Wave, Laplace and Diffusion equations by the method of separation of variables.
4. Deal with problems in applied mathematics, theoretical mechanics and mathematical physics and engineering.

Unit I

Linear Integral Equations-Definition and Classification of conditions, Special kinds of Kernels, Eigen values and Eigen functions, Convolution integral, Inner product, Integral equations with separable Kernels.

Unit II

Reduction to a system of algebraic equations, Fredholm alternative, Fredholm Theorem, Fredholm alternative theorem, Approximate method, Method of successive approximations, Iterative scheme.

Unit III

Solution of Fredholm and Volterra integral equation, Results about resolvent Kernel. Singular integral equation, Abel integral equation, General forms of Abel Singular integral equation, Weakly singular kernel Cauchy principal value of integrals.

Unit IV

Hilbert kernel, Hilbert formula, Solution of Hilbert type singular integral equation of first and second kind. Fundamental properties of Eigen values and Eigen functions for symmetric kernels.

Unit V

Cauchy's method of characteristic, Cauchy's problem for Homogenous wave equation, Properties of Harmonic function, Energy equation, Methods of separation of variable forsolving Laplace, wave and diffusion equations.

Books Recommended:

1. P. Kanwal, Birkhäuser: Linear Integral Equations (2^{nd} ed.), RInc., Boston.
2. T. Amarnath: An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, 2005.
3. I. N. Sneddon: Elements of Partial Differential Equations, Mc -Graw Hill, 1988.
4. Tyn Myint-U: Partial Differential Equations of Mathematical Physics, Elsevier Publications.

MACC-105: Fluid Mechanics I

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. understand the concept of fluid and their classification, models and approaches to study the fluid flow.
2. formulate mass and momentum conservation principle and obtain solution for non-viscous flow.
3. know potential theorems, minimum energy theorem and circulation theorem.
4. understand two dimensional motion, circle theorem and Blasius theorem.

Unit I

Types of fluids, Continuum hypothesis, Lagrangian and Eulerian method of describing fluid motion, Motion of Fluid element: Translation, Rotation and Deformation. Stream lines, Path lines and streak lines. Material derivative. Acceleration of a fluid particle in Cartesian, Cylindrical Polar and Spherical Polar Coordinates. Vorticity Vector, Vortex Lines, Rotational and Irrotational motion of fluid, Rotational velocity, Velocity Potential, Boundary surface, Boundary condition.

Unit II

Reynold transport theorem. Principle of conservation of Mass-Equation of continuity (By Lagrangian and Eulerian method. Equation of Continuity in different coordinate systems. Body force and Surface force. Euler's equation of motion-conservation of momentum, Bernoulli's Equation, Energy Equation, Impulsive effects.

Unit III

Irrotational motion in two dimensions: Stream function, Physical significance of stream function, Sinks, Doublets and their images in two dimension. Complex Velocity Potential. Sources, Milne-Thompson circle theorem.

Unit IV

Vortex, Vortex motion, Image of Vortex, Kelvin Circulation Theorem, Complex potential due to Vortex, Kirchhoff vortex Theorem, Blasius Theorem and Kutta-Joukowski Theorem.

Unit V

Irrotational motion produced by motion of circular cylinders in an infinite mass of liquid, Liquid Streaming past circular cylinder, Kinetic energy of liquid, Motion of sphere through a liquid at rest at infinity. Liquid streaming past a fixed sphere, Axis-Symmetric flow, Stoke's function.

Books Recommended:

1. G. K. Bachelor: An Introduction to Fluid Dynamics. Cambridge University Press. London.
2. Frank Chorlton: Text Book of Fluid Dynamics, C.B.S. Publishers, Delhi.
3. Z.U.A. Warsi: Fluid Dynamics, Theoretical and Computational Approaches, C.R.C. Press
4. S.W. Yuan: Foundation of Fluid Mechanics, Prentice Hall of India Pvt. Ltd. New Delhi
5. N. Curle and H J Davies: Modern fluid dynamics
6. R.W. Fox, P.J. Pritchard and A.T. McDonald: Introduction to Fluid Mechanics, Seventh
   Edition, John Wiley & Sons, 2009.

MAVC-101: Measure Theory & Integration

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Display understanding of the essential foundations of important aspect of mathematical analysis.
2. Explain the measurability of a set of real numbers and measurable functions.
3. Differentiate between the Riemann integral and the Lebesgue integral.
4. Apply the Measure theory and theory of the integral in other branches of pure and applied mathematics.

Unit I

Algebra of sets, countable sets, Cantor set, Borel sets, outer measure of a set and its properties. Measurable sets.

Unit II

Lebesgue measure, a non-measurable set. Measurable functions and their properties. Concept of almost everywhere. Littlewood's three principles.

Unit III

The Lebesgue integration of bounded function over a set of finite measure, the Lebesgue, Bounded convergence theorem, the integral of a non-negative function, Fatou's Lemma, Monotone convergence theorem, the general Lebesgue integral, Lebesgue convergence theorem.

Unit IV

Differentiation of monotone functions, Vitali's Lemma, the four derivatives, the differentiation theorem. Functions of bounded variation, Differentiation of an integral. Absolute continuity.

Unit V

Inequalities and the Lp Spaces: The Lp Spaces, convex functions, Jensen's inequality, the inequalities of Holder and Minkowski, completeness of Lp(μ). Convergence in Measure, almost uniform convergence.

Books Recommended:

1. H.L. Royden: Real Analysis, Pearson Prentice Hall
2. G.de Barra: Measure Theory and Integration, Wiley Eastern Ltd.

SEMESTER –II

MACC- 201: Topology II

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Define and illustrate the concepts of the separation axioms and its properties.
2. Understand the properties of topological spaces like connectedness and compactness.
3. Form new topological spaces by using Product Topology.
4. Provide different examples of homotopy, covering spaces under algebraic topology.

Unit I

Separation axioms T_3 $T_{31/2}$,T_4 and their basic properties (Hereditary and Topological properties), Dyadic fraction, Urysohn's lemma, Tietze extension theorem.

Unit II

Compactness and its basic properties, Compactness in metric spaces, Bolzano-Weierstrass property, Sequential compactness in metric space, countable compactness, Local compactness, One point compactification, Lebesgue Covering Lemma.

Unit III

Connected spaces and their basic properties, connectedness on the real line, Components of Topological Spaces, Locally connected spaces.

Unit IV

Tychonoff product topology in terms of standard sub-base and its characterization, Projection mappings, product spaces with separation axioms, Compactness, Connectedness and Countability, Embedding and metrization, Embedding lemma and theorem, Urysohn'smetrization theorem.

Unit V

Homotopy of paths. The fundamental group, Covering Spaces, Fundamental group of circle and the fundamental theorem of algebra.

Books Recommended:

1. James R Munkres: Topology, A first course, Prentice Hall, New Delhi, 2000
2. GF Simmons: Introduction to Topology and Modern Analysis, McGraw-Hill Book Company (1963) .
3. J.L. Kelley: General Topology, Van Nostrand. Reinhold Co, New York 1995.

MACC-202: Module Theory

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Identify cyclic modules, simple modules, finitely generated modules etc.
2. Find a basis of a free module
3. Use the basis to describe module homomorphisms
4. Describe the structure of a finitely generated module over a PID

Unit I

Modules-Definition and examples, simple modules, submodules, Module Homomorphisms, Quotient modules,

Unit II

Direct sum of modules, Exact sequences, Short exact sequence, split exact sequences. Five lemma, Torsion free and torsion modules

Unit III

Free modules- Definition and examples, modules over division rings are free modules, invariant rank property.

Unit IV

Free modules over PID's, Invariant factor theorem for sub modules, Finitely generated modules over PID, Chain of invariant ideals, Fundamental structure theorem for finitely generated module over a PID,

Unit V

Projective and injective modules, Divisible group.

Books Recommended :

1. S. Lang: Algebra, Addison Wesley.
2. V.Sahai &V.Bist: Algebra, Fourth Edition, Narosa.
3. I.B.S.Passi and I.S.Luther: Algebra, Volume 3 Modules, Narosa

MACC-203: Riemannian Manifolds, Lie Algebra and Bundle Theory

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Use Riemannian metric for studying various types of curvatures in a manifold and to calculate Ricci tensor & Ricci curvature.
2. Recognize whether a given manifold is Einstein or not.
3. Explain Levi civita connection, koszulconnection and other important connections which are used in manifolds.
4. Understand the concept of tensors and forms .
5. Understand covariant derivative and contraction in manifold.
6. Understand Lie groups and linear algebra with examples

7. Explain the idea of principal fibre bundle linear fibre bundle and relation between them.

Unit I

Sectional Curvature, Schur's Theorem, Riemannian Manifold , Geodesic in a Riemannian Manifold, Projective Curvature tensor, Concircular Curvature Tensor, Conformal curvature tensor, Conharmonic curvature tensor, Einstein Manifolds.

Unit II

Levi-Civita connection, Linear connection, Semi-symmetric connection, Quarter symmetric connection, Koszul connection, Ricci identity.

Unit III

Tensor and forms, Exterior derivative, contraction, Lie derivative, general covariant derivative.

Unit IV

Lie groups and Lie algebras with examples, homomorphism, isomorphism, one parameter subgroups and exponential map, The Lie transformations group.

Unit V

Principal fibre bundle, Linear frame bundle, Associated bundles, tangent bundle.

Books Recommended:

1. N.J. Hicks: Notes on Differential Geometry, D. Van Nostrand, 1965.
2. B.B. Sinha: An introduction to Modern Geometry.
3. U. C. De., A. A. Shaikh: Differential Geometry of Manifolds, Narosa Publishing House.

MACC-204: Ordinary Differential Equations

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Solve the system of 1st order differential equations, 2^{nd} order differential equations, nth order differential equations, oscillatory equation, stability and un-stability of linear and non-linear system of equations
2. Conceptualize Green's functions and nature of critical points
3. Prove advanced understanding of topics in applied mathematics, computational physics etc.

Unit I

Linear System- Introduction, properties of linear homogeneous systems, Abel-Liouville formula, Periodic linear System, Floquet's theorem, Solution of nth order linear homogeneous equation with variable coefficients.

Unit II
Inhomogeneous linear system, nth order linear non-homogeneous equation with variable coefficients, Hurwitz's theorem, Non-linear system, Volterra's prey & predator equation, Non Linear equation: Autonomous system.

Unit III

The phase plane & its phenomena, types of critical points & Stability, Critical points & stability for linear system, stability by Liapunov's direct method.

Unit IV

Green function, Construction of Green functions, Green function of homogeneous and non-homogeneous end conditions, Strum Liouville systems.

Unit V

Second order differential equation: Introduction, Preliminary results, Boundedness of solutions, Oscillatory equation, number of zeroes, Pruffer's transformation, Strum theorem, Strum's comparison theorem.

Books Recommended :

1. G.F. Simmons: Differential Equation, Tata McGraw-Hill
2. B. Rai, D.P. Chaudhary, H.I. Freedman:A course in Ordinary Differential Equations, Narosa Publishing House.
3. E. A. Coddington: An Introduction to Ordinary Differential Equations
4. S. L. Ross: Differential Equations, Wiley Indian, 2004

MACC-205: Complex Analysis

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Understand further deeper topics of Complex Analysis and basic topics needed for students to pursue research in pure Mathematics
2. Understand the properties of maximum modulus of a Complex valued function and the results based on that property
3. Develop manipulation skills in the use of Rouche's theorem and Argument Principle
4. Show knowledge of Gamma and Zeta functions with their properties and relationships
5. Understand the Harmonic functions defined on a disc and concerned results
6. Make factorization of entire functions having infinite number of zeros

Unit I

Schwarz's Lemma, Minimum Modulus Theorem, Hadamard's three circle theorem, automorphism of the unit disk. Convergence of sequences and series of complex numbers, absolute convergence.

Unit II

Uniform convergence of sequence and series of functions, Cauchy's criterion, Weierstrass's M-test, analytic convergence theorem. Absolute and uniform convergence of power series, integration and differentiation of power series, radius of convergence.

Unit III

Zeroes of holomorphic functions, Open Mapping Theorem, Inverse Function Theorem. Index of a closed path, meromorphic functions, argument principle, Rouche's theorem, residue at the point at infinity, indentation around a branch point and the branch cut, summation of series.

Unit IV

Function spaces: Hurwitz theorem, Infinite products, Weierstrass factorization theorem, Mittag-Leffler's theorem, Gamma functions and its properties, Riemann's Zeta function.

Unit V

Uniqueness of direct analytic continuation, Power series method of analytic continuation, Natural boundary, Schwarz's reflection principle, Harmonic Functions, Mean value property for harmonic functions, Harnack's inequality, Poisson formula, Jensen's formula, Poisson-Jensen's formula, Convex functions, Hadamard's three circle theorem as a convexity theorem, Canonical products, Hadamard's factorization theorem, order of entire functions.

Books recommended:

1. J. V. Deshpande: Complex Analysis, Tata McGraw-Hill Publishing Company Limited, New Delhi
2. E. C. Titchmarsh: Theory of functions, Oxford University Press
3. John B. Conway: Functions of one complex variables, Springer International
4. R.V. Churchil & J.W. Brown: Complex Variables and Applications, McGraw-Hill Publishing Company Limited.

MACC-206: Fluid Mechanics II

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Understand the concept of fluid and their classification, models and approaches to study the fluid flow
2. Formulate mass and momentum conservation principle and obtain solution for non-viscous flow.
3. Understand two dimensional motion, circle theorem and Blasius theorem
4. Understand the concept of stress and strain in viscous flow and to derive

Navier Stokes equation of motion and solve some exactly solvable problems

Unit I

Newton's law of viscosity, Nature of stress, Stress component in real fluid, Symmetry of stress tensor. Transformation of stress components. Stress invariants, Principal Stresses, Nature of Strain, Rates of strain components, transformation of rate of strain components, Rate of Strain Quadric, Relation between Stress and rate of Strain, Boundary conditions for viscous fluid.

Unit II

Navier-Stokes equation of motion-Conversation of momentum. Navier-Stokes equations in orthogonal coordinate systems (particularly in Cartesian, cylindrical and spherical coordinate systems), Energy Equation-Conversation of Energy. Energy dissipation function. Energy dissipation due to viscosity. Diffusion of vorticity.

Unit III

Plane Poiseuille and Couette flows between two parallel plates, Steady viscous flow through tubes of uniform cross-section in form of circle, ellipse and equilateral triangle under constant pressure gradient. Flow between two co-axial cylinders and concentric spheres, unsteady viscous flow over a flat plate.

Unit IV

Dynamical similarity, Reynolds number, slow viscous flow, Stoke's flow. Solution of Stokes equations, uniform flow past a sphere at low Reynolds number, torque and drag on a sphere due to a uniform flow. Flow past a circular cylinder, Stokes paradox.

Unit V:

Prandtl's Boundary layer concept, Boundary layer thickness-displacement, momentum of energy. Momentum and energy integrals, condition for separation, boundary layer flow along a semi-infinite plate in a uniform stream, Blasius solution.

Books Recommended:

1. G. K. Batchelor: An Introduction to Fluid Dynamics
2. Frank Chorlton: Text Book of Fluid Dynamics, C.B.S. Publishers, New Delhi.
3. Z.U.A. Warsi: Fluid Dynamics, Theoretical and Computational approaches, C.R.C. Press
4. S.W. Yuan: Foundation of Fluid Mechanics, Prentice Hall of India Pvt. Ltd., New Delhi
5. L. Rosenhead: Laminar Boundary layer, Oxford Press
6. R.W. Fox, P.J. Pritchard and A.T. McDonald: Introduction to Fluid Mechanics, Seventh Edition, John Wiley & Sons, 2009
7. Happel, J. and Brenner, H.: Low Reynolds Number Hydrodynamics with Special Applications to Particulate Media, Prentice-Hall, Inc., Englewood Clis, N.J., 1965

MAVNC-201: Mathematical Modeling

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Understand the fundamental models of mathematics.
2. Apply the knowledge of the subject in solving real life problems.

Unit I

Basics of number theory, modelling events using calculus, importance of function graphs, simple equations

Unit II

Discrete numeric functions, difference equations

Unit III

Solving problems using trigonometric functions, basic mathematical functions with applications

Unit IV

Real life networking models, PERT and its industrial applications

Unit V

Study of different Number systems

Books Recommended:

1. Aris, Rutherford: Mathematical Modelling Techniques, New York: Dover. ISBN 0-486-68131-9
2. Bender, E.A.: An Introduction to Mathematical Modeling, New York: Dover. ISBN 0-486-41180-X
3. Gershenfeld, N.: The Nature of Mathematical Modeling, Cambridge University Press ISBN 0-521-57095-6 .
4. Lin, C.C. & Segel, L.A.: Mathematics Applied to Deterministic Problems in the Natural Sciences, Philadelphia: SIAM. ISBN 0-89871-229-7

SEMESTER -III

MACC-301: Functional Analysis

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Apply Holder and Minkowski inequalities
2. Construct conjugate of a linear operator
3. Basic understanding of orthogonal and orthonormal sets
4. Construct complete orthonormal basis from a given linearly independent set
5. Describe the applications of spectral theorem

Unit I

Banach Spaces- the definition and some examples, continuous linear transformations, The Hahn Banach theorem.

Unit II

The natural imbedding of N in N**, the open mapping theorem, the conjugate of an operator.

Unit III

Hilbert spaces- the definition and some simple properties, Orthogonal complements, orthogonal sets, the Conjugate space H*.

Unit IV

The adjoint of an operator, Self adjoint operators, normal and unitary operators, Projections.

Unit V

Finite dimensional spectral theory – Spectrum of an operator, the spectral theorem, uniqueness of spectral decomposition.

Books Recommended :

1. G. F. Simmons: Introduction to Topology & Modern Analysis (McGraw Hill).
2. V.B.Limaye: Functional Analysis, Wiley Eastern.

MACC-302: Structures on Almost Complex Manifolds

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Explain the concept of even dimensional manifolds and their examples
2. Understand the concepts of contravariant almost analytic vector fields, covariant almost analytic vector fields, killing vector fields and their applications

3. Apply various concept of differential calculus to the settings of abstract set called manifold.
4. Show applications of Kahlermanifolds in superstring theory and in general relativity

Unit I

Almost complex manifolds, Nijenhuis tensor, contravariant and covariant analytic vector and their properties.

Unit II

Almost Hermite manifold, almost analytic vector fields curvature tensors, Linear connections and their properties.

Unit III

Kahler manifolds, affine connections, curvature tensors, contravariant almost analytic vectors.

Unit IV

Nearly Kahler manifold, curvature identities, Curvature tensors, almost analytic vectors.

Unit V

Almost Kahler manifolds, analytic vectors conformal transformations, curvature identities.

Books Recommended :

1. R.S. Mishra, Structures on a differentiable manifold and their applications, Chandrama Prakashan, Allahabad.
2. U. C. De., A. A. Shaikh, Complex manifolds and contact manifolds, Narosa Publishing House.

MAEL -301A: Advanced Ordinary Differential Equations

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Solve an ordinary differential equation, and characterize its solution
2. Understand the existence, uniqueness, and other properties of a solution of differential equations
3. Introduce the problems focusing on areas where mathematical ideas have had a major impact on human inquiry
4. Describe a physical problems into a differential equation
5. Show understanding of the differential equation (ordinary and partial both)
6. Analyze the structure of real-world problems and plan solutions strategies
7. Derive the properties of solutions of differential equations

Unit I

Existence and uniqueness of theorem. Dependence of solutions on initial conditions. Dependence of solutions on parameters.

Unit II

General theory of Linear Differential Equations: Existence of solutions , Basic theory of the homogeneous linear system, The nonhomogeneous linear system, Linear independence and Fundamental Systems, properties of the homogeneous Linear equation, reduction of order, the non homogeneous equation, the adjoint vector equation, self-adjoint vector equation.

Unit III

Matrix methods for homogeneous linear systems with constant coefficients: Two equation and two functions and two unknown functions, Example of the Matrix Methods. Eigenvalue problems, Green's matrix and its properties. Solutions of boundary value problem by Green's matrix.

Unit IV

Sturm-Liouville System, Eigen functions, Bessel functions, Singular Sturm Liouville systems, Legendre functions boundary value problem for ordinary differential equation. Solution by Eigenfunction Expansion, and Green's functions, construction of Green's function for Ordinary differential equation.

Unit V

Zeroes of solutions, Strums separation and comparison theorems. Oscillatory and nonoscillatory equations, Riccati's equation and its solution, Pruffer transformation, Lagrange's identity and Green's formula for second-order equation.

Books Recommended:

1. S.L. Ross: Differential Equations Blaisdell Publishing Company.
2. R.H.Cole: Ordinary Differential Equation by Appleton-Century-Crofts, New York.
3. S.L.Rose: Differential equations by Wiley Indian edition.

MAEL-301B : Cryptography

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Have a broad theoretical background in cryptography and information security
2. Apply number theory in cryptography
3. Have good knowledge of information security and cryptography which will help them to go in the field of research and industry

Unit I

Secure communication, cryptographic applications, Symmetric cipher model, Substitution technique: Ceasar cipher, Mono-alphabatic cipher, Playfair cipher, Hill cipher, polyalphabatic cipher, one time pad, Transposition techniques, cryptanalysis of classical ciphers.

Unit II

Pseudorandom bit generator, Blum Blum Shub generator, linear feedback shift register sequences, Nonlinear feedback shift register, Stream cipher, Modern stream ciphers, RC4 stream cipher.

Unit III

Block cipher, Feistel cipher, simplified DES, Data encryption standard (DES), Advance encryption standard(AES), S-box design of DES and AES, Boolean functions, bent functions, construction of finite fields, modular polynomial arithmetic. Mode of operations, Attacks on block cipher.

Unit IV

Public key cryptosystem, RSA cryptosystem, RAS and factoring, Rabin encryption , Key management, Diffie Hellman key exchange, discrete logarithm, ElGamal encryption, Message integrity, cryptographic hash function, Hesh function based on block ciphers, Message authentication, Message authentication codes(MAC), digital signature, RSA digital signature scheme, ElGamal digital signature scheme.

Unit V

Factoring: p-1 method, quadratic sieve, discrete logarithm: DL problem, Shanks Babystep Giant step algorithm, Pollard pho algorithm, Pohlig-Hellman algorithm, Elliptic curves, Elliptic curve arithmetic, Elliptic curve cryptography

Books Recommended:

1. Johannes A. Buchmann: Introduction to cryptography, Springer
2. William stallings: Cryptography and network security Principles and practices, Pearson
   education
3. Alferd J. Menezes, Paul C. Van Oorschot, Scott: A Handbook of applied cryptography,
   Vanstone, CRC press
4. Wade Trappe, Lawrance C.: Introduction to cryptography and coding theory, Washington
5. Behrouz A. Forouzan: Cryptography and network security, Tata McGraw-Hill
6. JosefPieprzyk, Thomoshardjono, Jennifer Seberry: Fundamentals of computer security,
   Springer

MAEL 302 A: Discrete Mathematics

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Display familiarity with the mathematical models which are the integral part of the hardware and software of computer science
2. Elaborate and expand their understanding of the tools helpful in the implementation of circuit design, AI algorithms and compiler construction.

Unit I

Mathematical Logic, Statement calculus: Propositional logic, Logic operators or connectives, Well formed formula (wff), Construction of truth-table for a formula, Equivalence of formulas, Tautology, Contradiction argument, Valid argument, Proving validity by truth-table methods, Inference theory of statement calculus, Minimal sets of logic operators. Predicate calculus: Statement function and statement, Proving validity by the deduction method.

Unit II

Lattice theory and Boolean Algebra Lattice Theory: partial order relation, Partially ordered set, Totally ordered set, Hasse Diagrams, Lattice, Lattice as an algebraic system, Bounded lattice, Complemented lattice, Distributive lattice, Direct product, Lattice homomorphism

Unit III

Boolean algebra: Boolean functions, Principle of duality, Boolean function minimization, Sum of products and product of sums form, Normal forms, Conversion of normal forms into principal normal forms, Boolean function minimization, Logic circuits, Designing of logic circuits.

Unit IV

Automata theory, Finite state automaton, Types of automaton, Deterministic finite state automaton, Non deterministic finite state automaton, Equivalence of NFA and DFA, Finite state Machines: Moore and Mealy machine.

Unit V

Grammars and Languages, Regular language, Regular expression Equivalence of Regular language and finite state automaton, Grammar: Context-free and Context-sensitive grammar, LR Grammar: Construction of LR(0) parsing table, Construction of LR(1) parsing table, Decision algorithms for CFL.

Books Recommended:

1. Mendelson, Elliott: Introduction to Mathematical Logic, Chapman & Hall, 1997
2. John E. Hoprcroft, Rajeev Motwani, Jeffrey D. Ullman: Introduction to Aotomata Theory Languages and Computation, Pearson Education, 2000

3. Arnold B. H.: Logic and Boolean Algebra, Prentice Hall, 1962
4. K. H. Rosen: Discrete Mathematics and its applications, MGH 1999

MAEL-302B: Approximation Theory

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Understand the concept of interpolation processes, finite element methods etc.
2. Apply the knowledge of the theory, in research on this area.
3. Use famous Weierstrass Approximation theorem, first lacunary interpolation i.e., (0, 2) interpolation and Spline interpolation.

Unit I

Different types of Approximations, Weierstrass Approximation Theorem, Monotone operators, Markoff inequality, Bernstein inequality.

Unit II

Hermite and HF interpolation, Fejérs theorem for HF interpolation, Lobatto and Radau Quadrature formulas, (0, 2)-interpolation on the nodes of $\pi_n(x)$, existence, uniqueness.

Unit III

Explicit representation of (0, 2) interpolation, Effectiveness of Least squares approximation as Uniform approximation.

Unit IV

Erdös-Túran Theorem, Jackson's theorems (I to V), Dini-Lipschitz theorem, Inverse of Jackson's theorem, Bernstein Theorems (I, II, III), Zygmund theorem.

Unit V

Spline interpolation, existence, uniqueness, Explicit representation of cubic splines, certain extremal properties and uniform approximation.

Books Recommended:

1. T.J. Rivlin: An Introduction to the Approximation of Functions, Dover Publications, NY.
2. E. W. Cheney: Introduction to Approximation Theory, McGraw-Hill Book Company.
3. A. Ralston: A First Course in Numerical Analysis, McGraw-Hill Book Company.

MAIN -301 Summer Internship

MAIER-301A: Mathematics in Computer Designing

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Show familiarity with the awareness and understanding of day-to-day applications of mathematics specially in computer sciences
2. Possess insights related to computer's hardware and software design

Unit I

Preliminary concepts of mathematical functions and relations.

Unit II

Number theory, study of residues.

Unit III

Mathematical equations and matrices.

Unit IV

Applications in computer hardware design.

Unit V

Elementary applications in software design.

Books Recommended:

2. Ellen Ullman: Close to the Machine
3. Eric Raymond: The Art of Unix Programming
4. Donald Knuth:- The Art of Computer Programming
5. Richard M. Stallman: Free Software, Free Society
6. Richard P. Gabriel: Patterns of Software
7. Richard P. Gabriel: Innovation Happens Elsewhere
8. Keith Curtis: After the Software Wars

MAIER-301B Astronomy & Astrophysics

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Use Celestial Coordinates system to specify the positions of stars, planets, satellites, galaxies and other celestial objects in three dimensional space
2. Explore the parent star Sun and its importance for sustaining life on the earth

3. Show familiarity with techniques to explore the solar surface temperature
4. Understand the solar atmosphere and its effect on the Earth and other planets
5. Understand the origin of the solar system
6. Explore the Terrestrial, Jovian & Dwarf planets, Comets and Meteoroids.
7. Describe the formation and evolution of stars which is a key research field for all major questions in astrophysics and cosmology
8. Deduce the implications for reionization and the early stages of chemical and photometric evolution of galaxies observed at high redshift
9. Illustrate Hertzsprung-Russell Diagram which is a graphical tool that astronomers use to classify stars according to their luminosity, spectral type, color, temperature and evolutionary stage
10. Plot the stars on the H-R diagram according to their temperatures, spectral classes, and luminosity by which astronomers can classify stars into their different types
11. Show understanding about the Binary star systems which are very important in astrophysics because calculations of their orbits allow the masses of their component stars to be directly determined, that in turn allows other stellar parameters, such as radius and density, to be indirectly estimated
12. Describe that the Galaxies are organized clusters of billions of stars, gas, dust, and matter in all other forms, all bound by the force of gravity
13. Provide details about their Milky Way, the galaxy containing our universe

Unit I: Celestial sphere

Constellations and nomenclatures of stars, The cardinal points and circles on the celestial sphere, Coordinate system, Equatorial, Ecliptic system, Hour angle, Twilight, Spherical triangle, Polar triangle and related problems.

Unit II: The Sun and Planets

Sun: Interior structure of the Sun, atmosphere, solar activity, sunspots and magnetic field, solar wind**.**
Planets: Study of Terrestrial planets, Jovian planets- their surface features & atmospheres. Tidal forces, Roche limit.
Dwarf planets: Definitions and locations.
Debris of the Solar system: Comets, Asteroids, Meteoroids.

Unit III: Stellar Structure and Evolution

Stars: Magnitude scales, Colour index, Basic of star formation and evolution.
Hertzsprung-Russell (HR) diagram, Spectral classification, Energy generation of stars.
Basics of degenerate remnants of stars: White dwarfs, Neutron stars, Pulsars, Black Holes, Chandrasekhar limit.
Stellar interiors: Hydrostatic equilibrium, Pressure equation of state, Energy sources, Energy transport and convection.

Unit IV: High Energy Astrophysics

Observational tools: Blackbody radiation, Specific intensity and flux density, Stellar parallax.
Formation & Structure of spectral lines, Radiative transfer.
Radiative processes in Astrophysics: Synchrotron emission, Energy loss and electron spectrum, Compton scattering, Bremstrahlung, Thermal bremstrahlung.
Binary stars: Classification, Accretion disks in binaries, Hulse-Taylor binary pulsar.

Unit V: The Milky way galaxy and Galaxies beyond

What are Galaxies & its types, The Milky Way Galaxy: Structure, Mass, Size. Hubble’s Classification, Formation of galaxies.

Books recommended:

1. W. M. Smart, Textbook on Spherical Astronomy, Cambridge University Press.
2. I.Todhunter, Spherical trigonometry, The Macmillan company, London.
3. Modern Astrophysics, B. W. Carroll and D. A. Ostlie, Addison-Wesley Publishing Co.
4. Eric Chaisson & Steve Macmillan, Astronomy Today, Prentice Hall, New Jersey.
5. John D Fix, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
6. Introductory Astronomy & Astrophysics, M. Zeilik and S. A. Gregory, 4th Edition, Saunders College Publishing.
7. Theoretical Astrophysics, Vol. I: Astrophysical Processes, T. Padmanabhan, Cambridge University Press
8. Theoretical Astrophysics, Vol. II: Stars and Stellar Systems, T. Padmanabhan, Cambridge University Press.
9. The Physical Universe: An Introduction to Astronomy, F. Shu, Mill Valley: University Science Books.
10. Textbook of Astronomy and Astrophysics with Elements of Cosmology, V. B. Bhatia, Pub-New Delhi, Narosa Publishing House.
11. The New Cosmos, A. Unsold and B. Baschek, New York:Springer Verlag.
12. The Physical Universe: An Introduction to Astronomy, F. Shu, Mill Valley: University Science Books.
13. Introduction to Cosmology, J. V. Narlikar, 3rd edition, Cambridge University Press.
14. Structure Formation in the Universe, T. Padmanabhan, Cambridge University Press.

SEMESTER-IV

MACC - 401 :Advanced Linear Algebra

Course outcome:

After the completion of the course, students are expected to have the ability to :

1. Find the minimal polynomial of an operator.
2. Compute Jordan canonical form of an operator and apply it to practical problems.
3. Demonstrate Cholesky. polar, singular value, QR and LU decompositions of a matrix.

Unit I

Review of characteristic values and characteristic vectors of linear operators, minimal polynomial, Primary decomposition theorem, Cayley Hamilton theorem.

Unit II

Diagonalisable and triangulable operators, simultaneous diagonalization and triangularization.

Unit III

Jordan canonical form, Jordan chain, Jordan block, Existence of Jordan canonical form, Applications of the Jordan form.

Unit IV

Unitary similarity, Schur decomposition, Method of least squares, Cholesky decomposition, Hadamard inequality

Unit V

Matrix decompositions – Polar decomposition, QR decomposition, LU decomposition, Singular value decomposition.

Books Recommended:

1. K. Hoffman and R. Kunze: Linear Algebra, Prentice Hall
2. V. Sahai and V. Bist: Linear Algebra, Narosa
3. H. Helson: Linear Algebra, Hindustan Book Agency

MAEL-401A : Advanced Partial Differential Equations

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Describe a physical problems in the form of differential equations
2. Solve the partial differential equation, and get characterized its solutions
3. Provide a sufficient knowledge to analyse the structure of real-world problems and plan solutions strategies
4. Understand the properties of solutions of differential equations
5. Understanding existence, uniqueness, and other properties of a solution of differential equations

Unit I

Introduction, basic concept and definition, classification of second order linear equation and method of characteristics, canonical form, Equations with constant coefficients, Supper position principle. Method of separation of variables.

Unit II

Boundary Value Problems, Maximum and Minimum Principles, Uniqueness and Stability theorem, Dirichlet problem for a Circle, Dirichlet Problem for a Circular annulus, Neumann problem for a Circle, Dirichlet problem for a Rectangular, Dirichlet problem involving Poisson equation.

Unit III

Fourier Transforms - Definition and properties, Fourier transform of some elementary functions, convolution theorem, Application of Fourier transforms to solve partial differential equations. Green’s functions and boundary value problems.

Unit IV

The Cauchy problem: The Cauchy problem, Cauchy-Kowalewsky Theorem, Hadmard example, Cauchy problem for homogeneous wave equations, Initial value problem, The Cauchy problem for Non-homogenous wave equation., The vibration string problem, Existence and uniqueness solution of the vibrating problem.

Unit V

Duhamel’s Principle: Wave Equations, Heat Conduction equations, solution of Heat Equation in two and three dimensions (Cartesian, polar and spherical coordinate system) in terms of Bessel’s and Legendre’s Functions,

Books Recommended:

1. TynMyint-U: Partial Differential Equations of Mathematical Physics, Elsevier Publication
2. I.N. Sneddon: Elements of Partial Differential Equations, McGraw-Hill, 1988

MAEL- 401B : Almost Contact Manifolds & F-Structure Manifolds

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Explain the concept of odd dimensional manifolds and their examples
2. Understand the concepts of Lie derivative, Sasakian manifolds, K-contact Riemannian manifolds, properties of curvature on these manifolds
3. Understand the concept of different submanifolds
4. Apply the course knowledge in super-gravity, superstring theory and in general relativity
5. Apply for advanced studies / research in this area

Unit I

Almost contact manifold, Lie derivative, affinity almost Co-Symplectic manifold.

Unit II

Almost Grayan manifold, almost Sasakian manifold, K-contact Riemannian manifold, Properties of curvature on these manifolds, Almost contact 3-structure, Para contact structure.

Unit III

Sasakian manifolds, quasi-Sasakian manifold, 3-structure metric manifold, Kenmotsu manifold, trans-Sasakian manifold and their properties.

Unit IV

Co-symplectic structure, F- structure manifold and their properties.

Unit V

Submanifolds of almost Hermite manifolds and Kahler manifolds, Almost Grayansubmanifolds.

Books Recommended:

1. R. S. Mishra: Structures on a differentiable manifold and their applications, ChandramaPrakashan, Allahabad
2. U. C. De., A. A. Shaikh: Complex manifolds and contact manifolds, Narosa Publishing house

MAEL-402A: Graph Theory

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Illustrate multiple applications of Graphs in real life
2. Make models which are used in designing networks of highways, railways and airways
3. Outline data structures. which are useful in computer science.

Unit I

Graph and its terminology, Directed and undirected graph, Multi graph, Simple graph, Complete graph, Weighted graph, Planar and non-planar graph, Regular graph, Graph isomorphism and homeomorphism, Euler's formula, Statement and applications of Kuratowski's theorem

Unit II

Representing graphs in computer system, Coloring of graph. Graph connectivity, Konigsberg bridge problem, Euleria path and Elerian circuit, Hamiltonian path and Hamiltonian circuit.

Unit III

Study of Shortest path and shortest distance, Dijkstra's algorithm, Paths between the vertices, Path matrix, Warshall's algorithm, cut point, bridge, cut sets and connectivity, Menger's theorem.

Unit IV

Tree and related terminology, spanning tree, Finding minimum spanning tree by Kruskal's algorithm and Prim's algorithm, inorder, preorder, and postorder tree traversals, Binary tree, Expression trees and reverse polish notation (RPN), RPN evaluation by stack.

Unit V

Flow network, Feasible flows, Multiple sources and multiple sinks, cut sets in flow network, Relation between flows and cuts, Max flow problem, Max flow min-cut theorem, Matching, Covering, Application of networks in Operations Research –PERT.

Books recommended:

1. Harary, Addison: Graph Theory Wesley 1969
2. D. B. West: Introduction to Graph Theory, Prentice Hall 1996.
3. Jonathan Gross and Jay Yellan: Graph Theory and its Applications, CRC 1998.

MAEL-402B: Wavelet Theory

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Make plans for higher level research in this area and get funded by the funding agencies
2. Learn about the mathematical analysis involved in WA
3. Know the short comings in the Fourier analysis and how Wavelets help in overcoming those difficulties
4. Review Fourier transformation, continuous wavelet transform, multi-resolution analysis and algebraic constructions, included in the course

UNIT I

Fourier and inverse Fourier transforms, Convolution and delta function, Fourier transform of Square integrable functions, Continuous Wavelet Transform: The Heisenberg uncertainty principle, the Shannon sampling theorem, Definition and examples of continuous wavelet transforms,

UNIT II

A Plancherel formula, Inversion formulas, the kernel functions, Decay of wavelet transform, Frames: Geometrical considerations, Notion of frames.

Unit III

Discrete wavelet transforms, signal decomposition (analysis), relation with filter banks, signal reconstruction.

UNIT IV

Multi resolution analysis, axiomatic description, the scaling function, construction of Fourier domain.

UNIT V

Orthonormal wavelets with compact support: the basic idea, Algebraic constructions, binary interpolation, spline wavelets.

Books Recommended:

1. Christian Blatter: Wavelets A Premier, AK Peters, 2002.
2. C.K. Chui: An Introduction to Wavelets, Academic press.
3. Daubechies: Ten Lectures on Wavelets, SIAM, Philadelphia.

MAMT-401: Master Thesis

MAIRA-401A: Mathematical Biology

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Identify and explain the role of mathematics in the process of modelling in the field of Natural and Social Sciences.
2. Apply the various growth models of population
3. Explain and apply the models of harvesting and Mutualism

Unit I

Continuous population Model for single species, Exponential population growth model, continuous population growth model: Malthes model for population growth , General population growth model, Qualitative Analysis: Equilibrium points, Stability Analysis, logistic population growth model and their qualitative analysis, logistic growth model for non isolated population .

Unit II

Insect Out break model: Spruce Budworm ,Continuous Single species population model with Delays: Introduction, General Delay model and Qualitative Analysis, Logistic model with time delay effects, equilibrium points & stability Analysis.

Unit III

Harvesting a single Natural population: Harvesting in Delayed recruitment models: Constant effort Harvesting, constant yield harvesting, population model with Age Distribution, Simple Discrete population model.

Unit IV

Continuous Models for Interacting Population: Interaction between species: two species models, definition of stability, community matrix approach ,Qualitative behaviour of community matrix, Competition: Lotka-Volterra models, Extension to Lotka-Volterra models, competition in field experiments , competition for space, Models for Mutualism.

Unit V

Predator: Prey interaction: Lotka-Volterra models, dynamic of simple Lotka-Volterra models, Role of density dependent in the Prey, Classic laboratory experiment on predator ,predation in natural system. Some predator- prey models .

Books Recommended:

1. J.D.Murrey: Mathematical Biology
2. Alan Hasting: Population Biology Concepts and Models, Springer
3. J.Mazumdar: An introduction to Mathematical Physiology &Biology
4. Fred Brauer,Carlos Castillo- Chivez: Mathematical Models in Population Biology and Epidemiology

MAIRA-401B: Astro-Biology

Course Outcomes:

After the completion of the course, students are expected to have the ability to :

1. Describe the origin and evolution of life in the cosmos: What is life? how did it form? and where is it?
2. Display understanding of relatedness and integration of disciplines to Astro-biology.
3. Show understanding of comets and their impact on our solar system
4. Study Quantum chemistry and its tools which provide the theoretical information regarding to the formation of molecules that plays an important role for the origin of life in the Interstellar medium, planetary and Cometary atmospheres.
5. Explain what kind of environment would be needed to allow life to begin by creating hypothetical conditions present on the early Earth.

Unit I: Introduction to Astrobiology

- **What is Astrobiology**: A brief description, applications and importance.
- **Prospects for life elsewhere in the Solar System**: Sites with the possibility of liquid water and prebiotic molecules.
- Organic molecules in Meteorites.
- Space Missions for exploring the possibility of life.

Unit II: Comets-The unexpected visitors and Astrobiology

- **Comets:** Structure, composition, classification & origin.
- Potential sources of prebiotic molecules for the early earth.
- Organic molecules and volatiles in comets.
- Cometary missions.

Unit III: From Interstellar Molecules to Astrobiology

- **Interstellar Medium:** Definition and composition of ISM.
- The relationship of Interstellar molecules to the origin of life.
- Formation of interstellar molecules: In diffuse clouds, cold dark clouds, hot molecular cores and grain surface.
- Organic molecules in circumstellar envelopes.
- Prebiotic reactions and RNA world.

Unit IV: Basic Quantum Chemistry

- **Quantum Astrochemistry:** Definition, approximation & application of Quantum chemistry to search the origin of life.
- **Methods of Computational Quantum Chemistry:** Application of computational techniques and Quantum chemical methods etc.
- Introduction and usages of Gaussian Programme package.

Unit V – Extra-terrestrial Intelligence

- **Origin of Life on Earth** - Theories about origin of life, Urey-Miller experiment.
- **Extrasolar Planets** – The Circum stellar habitable zone, The Inner limit and outer limit of HZ, Continuous habitable zone, Galactic habitable zone.
- Methods to detect Extrasolar planets.

Books Recommended:

1. C.N. Banwell: Fundamentals of Molecular Spectroscopy
2. Baidyanath Basu: An Introduction to Astrophysics
3. Exploring Chemistry with Electronic Structure methods - James B. Foresman&Aeleen Frisch.
4. Astrobiology: Future Perspectives- Pascale Ehrenfreund, William Irvine.
5. Lectures in Astrobiology Vol I - Muriel Gargaud, Bernard Barbier, Herve Martin & Jacques Reisse.
6. Lectures in Astrobiology Vol II- Muriel Gargaud, BernardBarbier, Herve Martin & Jacques Reisse.
7. Chemical evolution and Origin of Life- Horst Rauchfuss.
8. Comets and the Origin and Evolution of Life- Paul J. Thomas, Christopher F. Chyba & Christopher P. Mckay.
9. Life in Universe- Joseph Seckbach, Julian Chela Flores, Tobias Owen and Francois Raulin.
10. Eric Chaisson& Steve Macmillion, Astronomy Today, Prentice Hall, New Jersey.John D Fix, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.