Hamdard University Bangladesh

Department of Mathematics

Faculty of Science, Engineering and Technology



Syllabus
of

Master of Science (M. Sc.) in Mathematics
(1-Year and 2- Years Programs)

Introduction

The 1- year M. Sc. program in Mathematics offers high quality education and elevates the knowledge in the arena of Mathematics. It prepares the students to meet the challenges and the needs of 21st century. The courses in the syllabus are well designed to enable the students in learning of the Mathematics.

In order to obtain M. Sc. Degree in Mathematics, a student will have to study for one year in 2 Semesters. The student will have to complete 36 credits to earn the degree. Teaching for 12 hours is equivalent to 1 credit hour and will be treated as 1 credit. Each 3 credits course is a full unit course which requires contact hours: 36 $(\mathbf{3 \times 12})$. For such a course, there should be effective 36 classes- each of 01 (one) hour duration.

Academic System

Hamdard University Bangladesh follows a model of higher education which consists of courses, semesters, credit hours, continuous evaluation and letter grading. In keeping with its mission and vision, Hamdard University Bangladesh strives to ensure high academic standards by implementing well-designed curricula, selecting quality students and faculty carefully, utilizing modern and effective instructional methods and monitoring continuously with rigorous evaluation of all the pertinent activities. There are two options:

Option A (General Group): Under this option each student is required to study any ten (10) courses [each course 03 Credits carried 100 marks] and get examined as follows:

The distribution of marks for this option:

10 Theoretical unit courses $(\mathbf{3 \times 10})$	30 Credits
General Viva-voce Examination	03 Credits
Comprehensive Examination	03 Credits
Total:	**36 Credits**

Option B (Thesis Group): This option is restricted to regular university or college students who have secured an average of 60% marks in the B.Sc. (Honors) in Mathematics. Under this option each student has to fulfill the requirement:

(i) To study any 08 courses and take part in examination as furnished below.
(ii) To write a thesis on same topic under the guidance of a supervisor, with approval of the university.

The typescript thesis has to be submitted in triplicate to the university by a period of 120 days on completion of the written examination. This thesis shall be evaluated on 03 Credits.

(a) General Viva-voce Examination of 03 Credits (Conduced by examination committee), Comprehensive examination of 03 Credits.
(b) Oral defense of the thesis carrying 03 Credits.

The distribution of marks for this option:

08 Theoretical unit courses$(\mathbf{3 \times 8})$	24 Credits
General Viva-voce Examination	03 Credits
Thesis (Thesis evaluated on 03 Credits + Oral defense on 03 Credits)	06 Credits
Comprehensive Examination	03 Credits
Total:	**36 Credits**

Requirement for Admission for an Applicant

Those who have secured 50% marks/ Grade C+ (CGPA/GPA 2.50) in the B.Sc. (Honours) in Mathematics or M. Sc. Part- 1 Examination are eligible to apply for admission. After admission test, a merit list will be prepared. Then the selected students will be eligible for the admission.

Program and Semester Duration

The Hamdard University Bangladesh would confer the Degree of M. Sc. in Mathematics after a student has completed satisfactorily all the required courses which are offered over a maximum period of four academic years. The academic year is divided into two semesters.

The breakdown of these semesters is as follows:

Classes	20 weeks
Midterm Examination	02 week
Preparatory Leave	01 week
Semester Final Examination	02 week
Total:	**25 weeks**

Evaluation Policy

Every course will be supplemented by assignments, and marks will be allotted for the assignment. Marks will be in whole number; no fractional marks can be given. The distribution of marks for a course will be as follows:

Attendance	5%
Class test	10%
Assignment & Presentation	10%
Midterm Examination	25%
Final Examination	50%
Total:	**100%**

Thesis work will be done under the supervision of a Faculty member assigned by the Department. Evaluation of a thesis will be done by a committee (thesis evaluation committee) that would be constituted as follows:

Chairman	Thesis supervisor
Two Member	From the Department
One Member	External
Ex-officio Member	Head of Mathematics Department

Grading System

The grades at the university will be indicated in the following manner:

Numerical Grade	Letter grade	Grade Point
80 % - 100%	A+	4.00
75 % - < 80%	A	3.75
70 % - < 75 %	A-	3.50
65 % - < 70 %	B+	3.25
60 % - < 65 %	B	3.00
55 % - < 60 %	B-	2.75
50% - < 55 %	C+	2.50
45 % - < 50 %	C	2.25
40 % - < 45 %	D	2.00
Less than 40%	F	0.00

Grades without numerical value

P **:** Pass
I **:** Incomplete
W **:** Withdrawal

Pass/Fail Option

A course may be taken for a pass/fail grade, providing that the teacher approves the option and the student carries all the credits offered by the Department for regular letter grades in that semester. A maximum of 18 (eighteen) credits may be taken for credit with the pass/fail grading option. No more than 6 (six) credits may be taken with the pass/fail grading option in any one semester. Departments may not approve the pass/fail grading option for some courses counting towards the major.

Incomplete Grade

An Incomplete I grade is assigned only when a student has failed to complete one or more requirements of the course for unavoidable reason/accidental circumstance and has applied for I grade. The students who are permitted to appear in makeup examination (s) will be assigned an (I) grade for that course and this grade will stay until the student appears in the makeup examination at the first available opportunity; if he/she fails to appear in the makeup examination the (I) grade will automatically be converted to (F) grade.

Withdrawal (W)

The course withdrawal is assigned to a student who withdraws from the course within the deadline for withdrawal with ‘W’ grade. A student, who withdraws after this date, will earn the grade based on his performance before his withdrawal. Exception to this rule may be made on medical ground and in terms and conditions of the University.

Grade Point Average (GPA) Computation

The *GPA* is computed in the following manner:

$$\text{GPA} = \frac{\sum(\text{Credit Hour} \times \text{Grade Value})}{\sum \text{Credit Hour}}$$

$$\text{CGPA} = \frac{\sum(\text{No. of Credits} \times \text{Grade Value})}{\sum \text{No. of Credits}}$$

Grades Review Procedure

The Academic Council of the University administers the Grading Regulations and reviews course grades submitted by the Departments.

Academic Standing

Students should take the requisite number of courses and maintain satisfactory grades in the courses. They are expected to maintain a GPA of 2.00 (both semester and cumulative); otherwise, they will be put on probation for the following semester. Course grade can be improved in the next available opportunity by paying the applicable course fee. In case of 'F' grade, the student has to attend all the classes and the examination. Grade 'B-'and below can be considered to improve by the students.

Methods and Medium of Instructions

The university teaching meets the demand of the time adopting present-day teaching methods including interactive internet, simulation, lab work, case analysis and field study. A special feature of teaching at Hamdard University Bangladesh is the workshop/lab sessions designed to assist students in learning application of concepts (mostly activity- based education) and theories. The medium of instruction in Hamdard University Bangladesh is English.

Thesis Requirement

The thesis has to represent the contribution to fundamental knowledge to demonstrate the student's ability to identify and solve an acceptable problem in the area of Mathematical applications and to reflect the work in a document of acceptable literary quality. The appropriateness of the topic is determined by the Board of Post Graduate Studies (BPGS). In conclusion of the thesis, the thesis students must prepare for the corresponding thesis presentation.

Program Approval

Any Post Graduate program must receive the signed approval of the BPGS prior to the admission in that program.

Formation of Board of Post Graduate Studies (BPGS)

The Board of Post Graduate Studies (BPGS) would be constituted as follows:

Chairman	Head of Mathematics Department
Member	All teachers of this Department

Eligibility of Faculty Member Conducting the Course

A Faculty member, who would be chosen to conduct courses in M. Sc. in Mathematics program, has to at least one postgraduate degree. A Faculty member, who would be chosen to supervise the thesis of the postgraduate program, has to at least one postgraduate degree also.

M. Sc. Final Course Title

Course Code	Course Title	Credits
MAT601	Numerical Methods for Differential Equations	3 Credits
MAT602	Operations Research	3 Credits
MAT603	Magnetohydrodynamics	3 Credits
MAT604	Aerodynamics	3 Credits
MAT605	Fluid dynamics	3 Credits
MAT606	Differential and Integral Equations	3 Credits
MAT607	Quantum Mechanics	3 Credits
MAT608	Asymptotic and Perturbation Methods	3 Credits
MAT609	Similarity Analysis	3 Credits
MAT610	Computational Fluid dynamics and Heat Transfer	3 Credits
MAT611	Geometry of Differential Manifolds	3 Credits
MAT612	Theory of Relativity	3 Credits
MAT613	Lattice Theory	3 Credits
MAT614	Fuzzy Mathematical Structures	3 Credits
MAT615	Advanced Mathematical Methods	3 Credits
MAT616	Mathematical Modeling and Population Dynamics	3 Credits
MAT617	Rings and Modules	3 Credits
MAT618	Graph Theory	3 Credits
MAT619	Advanced Number Theory	3 Credits
MAT620	Real Function Theory	3 Credits
MAT621	General Algebraic Topology	3 Credits
MAT622	Functional Analysis	3 Credits
MAT623	Partial Differential Equations	3 Credits
MAT624	Biomathematics	3 Credits
MAT625	Industrial Mathematics	3 Credits
MAT626	Computational Stellar Astrophysics	3 Credits
MAT627	Dynamical Systems	3 Credits
MAT628	Operations Management	3 Credits
MAT629	Riemannian Geometry	3 Credits
MAT697	Viva Voce Examination	3 Credits
MAT698	Comprehensive Examination	3 Credits
MAT699	Thesis	6 Credits

M. Sc. Final Course Detailed Syllabus

MAT601: Numerical Methods for Differential Equations 3.00 Credit Hours

Introduction to Finite Element Method (FEM): Discretization, Construction of basic functions. Numerical integration; coordinate transformation, local and global derivatives, mesh generation, h-p convergence, finite element approximation of line and double integrals.
Method of Weighted Residuals: Subdomain, Collocation, Galerkin and Least-Squares methods. Matrix Formulation; Modified Galerkin techniques, Element/ stiffness matrix.
Finite element solution of Boundary Value Problems (BVP): Outline of FE procedures for 1-D and 2-D problems (Poisson's and Laplace's equations), Matrix Formulation, Element concept. Assembly. Triangular, Rectangular and Quadrilateral elements (linear and quadratic elements).
Variational Formulation of BVP: Functional and Variational Calculus. Construction of Functional, Finite Difference Method, Rayleigh Ritz Method and Finite elements**.** Review of Finite difference approximation. Applications to solve eigenvalue problems and higher order BVP.
Elliptic Partial Differential Equations (PDE): Difference equations for Poisson's and Laplace's Equations BVP, matrix formulation, Convergence by iterative methods, and error analysis.
Parabolic Problems: Derivation of difference formulas for IBVP. Matrix formulation. Heat Equation, Forward, Backward and Crank-Nicolson Methods, Difference methods in 2-space dimensions, ADI method. Stability and error analysis.
Hyperbolic Problems: Difference methods for a scalar IVP and IBVP, Lax-Wendroff and Courant-Friedrichs-Lewy explicit methods. Wendroff implicit method, Wave Equation in time dependent and two space dimension. Convergence and stability analysis.

Recommended References

P.E. Lewis and J.P. Ward	: The finite element method; Principles and Application.
O.C. Zienkiewicz and K. Morgan	: Finite Elements and approximations.
M.A. Celia and W.G. Gray	: Numerical Methods for Differential Equations.
G.D. Smith	: Numerical solution of Partial differential equations.
Paul DuChateau and David Zachmann	: Applied Partial Differential Equations.

MAT602: Operation Research 3.00 Credit Hours

Basics of Operations Research: Introduction, Definition. Characteristic. Necessity. Scope, Classification of problems, Types of mathematical models. Review of Linear Programming.
Transportation and Assignment problem: Introduction, Formulation. Relationship with LP, Solution procedure and Applications.
Network Models: Network definitions, Shortest Route problem, Minimal Spanning Tree problem and Maximal-Flow problem.
Integer programming: Introduction. Branch and Bound Algorithm, Cutting-plane Algorithm, Application.
Sequencing Problem: Sequencing problem processing n jobs through two machines, n jobs through three machines, two jobs through m machines, n jobs through m machines and approaches to more complex sequencing problems.

Matrix Game Theory: Introduction. Minimax-maximin pure strategies. Mixed strategies and Expected payoff, solution of 2×2 games, solution (2×n) and (m×2) games, solution of (m×n) games by linear programming and Browns algorithm.
Dynamic Programming: Introduction, Investment Problem, Production scheduling problem. Stagecoach problem, Equipment replacement problem.
Nonlinear Programming: Introduction, Unconstrained problem, Lagrange method for equality constraint problem, Kuhn-Tucker method for inequality constraint problem and Quadratic programming problem.

Recommended References

Hamdy A. Taha	: Operations Research.
Richard Bronson, Govindasami Naadimuthu	: Operations Research.
Anderson, Sweeney, Williams	: An Introduction to Management Science.
W. L. Winston, J. B. Goldberg	: Operations Research.

MAT603: Magnetohydrodynamics 3.00 Credit Hours

Introduction of MHD and its applications: State electromagnetic (Maxwell's) equations, discuss importance for various terms, State fluid equations-discuss mass continuity Navier Stokes and energy equations, MHD Approximation, Magnetic field visuaisation, The Lorentz force pressure and tension, Magnetohydrodynamic balance, Force-free fields.
The Induction Equation: The magnetic induction equation, Non-dimensinalisation and magnetic Reynolds number R_m, The diffusive ($R_m \ll 1$) and perfectly conducting limit ($R_m >> 1$), Alfen's frozen flux theorem, The Bondy Golg Theorem, The Cauchy solution, The induction and diffusion.
Static Magnetic Field: Rayleigh-Benard Convection, Hartman flow, Magnetohydordynamic fields, Plasma containment, Qualitative discussion of stability.
Waves: Linearisation of MHD equations, Modal expansion, Alfven speed, Alfven waves, Acoustic waves, Magnetoacoustic waves.
Dynamo Theory: Definition of dynamo, dynamo conditions, Classification of dynamos, Energetics, Cowlings theorem, Toroidal and Peloidal fields.

Recommended References

P.A. Davidson	: An Introduction to Magnetohydrodynamics
E.R. Pries	: Solar Magnetohydrodynamics
J.A. Shercliff. Pergamon	: A Text Book on Magnetohydrodynamics
R.T. Merill et al.	: The Magnetic field of the Earth: Paleomagnetism
H.K. Mofatt	: Magnetic field generating in electrically conducing.

MAT604: Aerodynamics 3.00 Credit Hours

Preliminary Notions: Aerodynamic force, lift and Drag. Chord of a Profile, Chord of an Airfoil. Aspect ratio, Geometrical incidence / Angel of attack.
Thermodynamic Conception: Thermodynamic Slate. Variables of state, Equation of state, the First Principal law of Thermodynamics, the concept of Entropy, I lie Second law. The Canonical equation of state. Free Energy and Free Enthalpy.

One Dimensional Motion: Continuity. Energy and Momentum Equations, Euler's Equation. Speed of Sound, Mach Number, Normal shock relation. Propagating Shock wave, the Acoustic equations, Propagation of Acoustic waves.
Two-Dimensional Motion: Oblique Shock waves, Supersonic Flow over a wedge, Mach lines: the Prandtl-Meyer function, Reflection of Oblique shocks. Mach reflection.
The General Equation of a Frictionless Flow of a Gas: The Continuity, Momentum and Energy Equations, The Eulerian Derivative. Natural coordinates, Crocco's Theorem.
Small Perturbation Theory: Induced/perturbed velocity. Derivation of the perturbation equations, Pressure coefficient. Boundary conditions. Two Dimensional flow past wave shaped Wall. Wavy wall in subsonic/supersonic flows, Supersonic thin airfoil theory.
Slender Body Theory: Axially symmetric flow, Subsonic and Supersonic flows. Yawed body of revolution in supersonic flow. Cross-Flow, Cross-Flow Boundary Conditions, Cross-Flow Solutions, Slender Bodies of Revolution.
Transonic Flow: Concept of transonic flow. Transonic range, Transonic flow past a wedge sections, the hodograph transformations and applications to nonlinear transonic flow field.
The Method of Characteristics: Hyperbolic equations, The compatibility relation. Axially symmetric flow, Non-isentropic flow, Intersection of waves.

Recommended References

H.W. Liepmann & A.Roshko	: Elements of Gas Dynamics.
L.M. Milne- Thomsen	: Theoretical Aerodynamics.
Shih- I Pai	: Viscous Flow Theory.
W.F. Durand	: Aerodynamic Theory

MAT605: Fluid dynamics 3.00 Credit Hours

Fundamental concepts: Newton's law of viscosity. Newtonian and non-Newtonian fluids. Body and surface forces, Stress and Rate of strain and their relation. Derivation of the Navier-Stokes equations of motion and its general properties.
Some exact solutions of the Navier-Stokes equations: Steady plane flows: Parallel flow through a straight channel and generalized Couettee flows, plane Poiseille flow, Flow through a circular pipe-the Hagen-Poiseulle flow, Flow between two coaxial cylinders, Flow between concentric circular cylinders.
Unsteady plane flows: Flow between two parallel plates, Flow over a suddenly accelerated flat plate, Flow over an oscillating plate.
Small Reynolds number flows: Differential equation of very low motion, Slow motion over a sphere, Hydrodynamic theory of lubrication.
Laminar boundary layer theory: General concepts and properties of boundary layer theory, Prandtl's boundary layer equations, Separation of a boundary layer, Similarity concepts and similarity solutions of the boundary layer equations, Flow in a convergent channel, Flow past a wedge, Boundary layer on a flat plate at zero incidence, Boundary layer flow with pressure gradient, Karman's integral equation, Application of Karman's integral equation (Karman- Pohlhasen method).
Thermal boundary layer in laminar flows: Derivation of the energy equation, Thermal boundary layer simplifications, Forced and Natural flows, Parallel forced flow past a flat plate at zero incidence, Natural flow past a horizontal vertical plates (some specific Problem).
Stability theory (onset of turbulence): Principles of the theory of stability of the laminar flows, Mathematical form of disturbances (Orr-Sommerfeld equation).

Turbulence: Definition of turbulence and its origin, Equations of motion for turbulent flows, Eddy viscosity concept, Prandtl's mixing length hypothesis, Von-Karman's similarity hypothesis.

Recommended References

H. Schlichting	: Boundary Layer Theory
D.J. Acheson	: Fluid Dynamics
I.Pop and D.B. Ingham	: Convective Heat Transfer
S. Kakac and Y.Yener	: Convective Heat Transfer

MAT606: Differential and Integral Equations 3.00 Credit Hours

Existence and uniqueness theorem for differential equations: Methods of successive approximations, Peano's existence theorem, fixed point methods, Continuation of solutions.
System of differential equations: Linear systems and their solutions by eigenvalue methods, variation of parameters, Exponentials with applications.
Integral equations: Conversions of IVP's to integral equations. Existence and uniqueness and general properties of solutions of Volterra integral equations, Linear system of VIE's, Resolvent kernel, Fredholm theory of IE's.
Stability theory: Stability of Linear and nonlinear systems of differential equations and Volterra integral equations, Liapunov functions and determinations of stability.
Periodic solutions: Periodic solutions of Linear and nonlinear differential and Intergral equations.

Recommended References

Morris W. Hirsch and Stephen Smale	: Differential Equations, Dynamical systems and Linear Algebra.
R.D Driver	: Introduction to Ordinary Differential Equations.
T.A. Burton	: Stability and Periodic Solutions of Ordinary and Functional Differential Equations.
Rama Mohana Rao	: Ordinary Differential Equations, Theory and Applications.

MAT607: Quantum Mechanics 3.00 Credit Hours

Origin of quantum theory: Black body radiation. Photoelectric effect, Compton effect, Bohr model, De Broglie's hypothesis, Wave properties of matter.
Wave function: wave-particle duality, wave packets, Heisenberg uncertainty principle.
Schrodinger equation: Expectation values, Operators, Ehrenfest's theorem. Time-independent Schrodinger equation & its general solution, Schrodinger equation in momentum space.
One dimensional example: Free particle, potential step, the square well, linear harmonic oscillator, periodic potential.
Formalism of quantum mechanics: Dynamical variables, Unitary transformations, Metric representations of wave functions and operators, The Schrodinger and Heisenberg pictures.
Schrodinger equations in three dimensions: Separation of the equation in different co-ordinates, free particle, square well potential, the hydrogen atom.

Angular momentum: Orbital angular momentum, the eigenvalues and eigenfunctions of L^2 and L_z, Spin angular momentum, Total angular momentum, addition of angular momenta.
Approximation methods: Perturbation theory (non-degenerate and degenerate cases), variational method.
Many-particle systems: System of identical particles, Bosons and Fermions, Two-electron atoms.

Recommended References

B.H. Bransden & C.I. Joachain	: Introduction to Quantum Mechanics.
L.I. Schiff	: Quantum Mechanics.
David J. Griffiths	: Introduction to Quantum Mechanics.

MAT608: Asymptotic and perturbation Methods 3.00 Credit Hours

Asymptotic Expansions: Definitions of asymptotic sequences, expansions, and series. Order symbols and Gauge functions, convergent versus asymptotic series, Uniqueness of asymptotic series, Elementary operations on asymptotic expansions.
Expansion of Integrals: Integration by parts. Laplace's method and Watson's Lemma, method of steepest descents, method of stationary phase. Transform integrals and their asymptotic evaluation.
Differential Equations: Singularities and asymptotic methods of solutions with a large or small parameter (WKB method), Transition points.
Asymptotic matching: Use of asymptotic matching for expansion of integrals. Straightforward expansions of sources of non-uniformity. The method of strained co-ordinates. The method of matched and composite asymptotic expansions.

Recommended References

J.D. Murray	: Asymptotic Analysis.
F. W.J. Olver	: Asymptotic and Special Functions.
A.H. Nafeh	: Perturbation Methods.

MAT609: Similarity Analysis 3.00 Credit Hours

Principle and illustrations of dimensional analysis, systematic calculation of dimensionless products, algebraic theory of dimensional analysis, different procedures, (Rayleigh; Buckingham pie-theorem, stepwise, echelon, proportionalities etc.) for the determination of dimensionless groups and its behaviour for some boundary value problems; Method of similude and introduction to fractional analysis of overall equations, a free parameter method for similarity solution applied to two dimensional boundary layer flows, method of separation of variables, similarity requirements for three dimensional. Axisymmetric velocity and thermal boundary layer laminar flows (both steady and unsteady), group theory method, absorption of parameters and natural co-ordinates in similarity variables, reduction of independent variables, similarity and natural co-ordinates on linearised compressible flow, supersonic and transonic similarity rules. Karman similarity criteria for turbulent shear layers.

Recommended References

A. K. Hazra	: Similarity Analysis

MAT610: Computational Fluid Dynamics and Heat Transfer 3.00 Credit Hours

Introduction to computational Fluid Dynamics (CFD) and Heat Transfer, Basics of the methods used in CFD and Heat Transfer, Conversion equations (mass, momentum, energy and chemical species), Finite and Finite Volume Methods, Grid Generation, space and time discretization schemes, Tri-Diagonal Matrix Algorithm (TDMA), Data Analysis, Data Fusion and Post Processing, The Role of Experimental data in CFD and Heat Transfer.

Recommended References

Abdulnaser Sayma : Computational Fluid dynamics
Dale A Anderson : Computational Fluid Mechanics and heat transfer.
John D. Anderson Jr : Computational Fluid Dynamics

MAT611: Geometry of Differential Manifolds 3.00 Credit Hours

Surfaces and properties of surface: Minimal surfaces, theorem of minimal surfaces, general solution of the natural equations, Riccati equation and its solution, equation of Weingarten. Gauss and Codazzi and their applications. Theoema Egrcegium, Fundamental theorem of surface theory.
Developable and Ruled surfaces: Envelop, characteristic, edge of regression, developable surface, property of lines of curvature on developable, ruled surface, fundamental coefficients and Gaussian curvature for ruled surface, tangent plane to a ruled surface.
Geodesics on a surface: Geodesics, differential equation of geodesics, geodesics on plane, surface, sphere, right circular cone, right helicoid, cylinder, torus etc., geodesic curvature K_g and its formulae. Liouville's formula, geodesic on a surface of revolution. Clairaut's theorem, Bonnet's formula, geodesics on Liouville surface. Gauss-Bonnet theorem, torsion of a geodesic, geodesic parallel.
Mapping of surfaces: Mapping, homeomorphism, isometric lines and correspondence, Minding theorem, conformal, isometric and geodesic mapping. Tissot's theorem.
Differentiable manifolds: Theory of differentiable functions, coordinate functions, charts and atlases, complete, compatibility, differentiable structures, differentiable manifolds, local representation of a function for charts, induced topology on a manifold.
Topology of a manifold: Manifold structure on a topological space, properties of induced topology, topological restrictions on manifolds.
Differentiation on a manifolds: Partial differentiations, equivalence relation and class, smooth map on manifolds, tangent space, tangent bundles, tensor and exterior bundles, tangent map on manifolds.
Vector fields on manifolds: C^{∞}-Vector fields on manifolds, coordinates of vector fields, set of vector fields, theorem on vector fields and its coordinates, Lie brackets of vector fields and properties of φ-related vector fields.

Recommended References

C. E. Weatherburn : Differential Geometry of Three Dimensions.
D. J. Struik : Lectures on Classical Differential Geometry
F. Brickell and R. S. Clark : Differentiable Manifolds: An Introduction.
F. W. Warner : Foundations of Differentiable Manifolds and Lie groups.

MAT612: Theory of Relativity 3.00 Credit Hours

Inertial frame, Galilean transformations, Michelson-Morley experiment, Absolute motion und historical survey. Lorentz transformations, postulates of the special theory of relativity, Lorentz transformation equation, Consequences of Lorentz transformations, relativistic formulae for velocity and acceleration. Minkowski's space and its properties.
Relativistic mechanics: Mass and momentum, Newton's laws of motion, equivalence of mass and energy, transformation formulae for momentum, energy, force and density. Relativistic optics, relativistic electrodynamics and relativistic fluid mechanics. Principle of covariance and principle of equivalence.
Relativistic field equations: Energy-momentum tensor, Principle of Mach and Einstein's law of gravitation, Schwrzschild's solution of Einstein's equation. Newton's law as first approximation.
The three crucial tests of the general theory of relativity.
Cosmology: Cosmology models: (a) Robertson-Walker model (b) Friedmann Model (c) Einstein's model (d) De Sitter model.
Introduction to unified field theory, String cosmology.

Recommended References

I.K. Goyal & K.P. Gupta : Theory of Relativity.
Steven Weinberg : Gravitation and Cosmology Principles and Applications of the General Theory of Relativity.
H. Rashid & N. Islam : Theory of Relativity.

MAT613: Lattice Theory 3.00 Credit Hours

Lattice: Definitions and elementary properties. Modular Lattices and applications to Abstract Algebra. Metric Lattices and distributive Lattices. Reducibility and independence. Complemented Lattices. Boolean algebra, Canonical form of a Boolean Algebra. Boolean Rings, Morphisms, Direct products.
Minimization problem: The Veitch-Darnaugh Map of a Boolean function: Five Variable and Six Variable: maps. Boolean Matrices, Dedekind's characterization of modular lattices. Atomic Lattices and Semimodular Lattices.
Birkhoffs characterization of distributive lattices. Representation of distributive lattices. Stone theorem, Natchbin theorem and Hashimoto's theorem. Distributive lattices with pseudocomplementation. Stone lattice and its characterizations. Stone algebra and its characterization. Distributive, standard and neutral elements. Distributive, standard and neutral ideals. Structure theorems.

Recommended References

G. Birkhoff : Lattice Theory
G. Gratzer : General lattice Theory
D.K. Rutherfor : Introduction to lattice Theory

MAT614: Fuzzy Mathematical Structures 3.00 Credit Hours

Constructing fuzzy sets, Operations on fuzzy sets, t-space and s-norms, α-cuts, Extension principle, Measurement of fuzziness, Fuzzy relations, Fuzzy similarity, Fuzzy ordering, Pattern classification based on fuzzy relations. Fuzzy relational equations. Representation theorems. Interval analysis, Arithmetic operations with applications. Multi-valued logics,

Fuzzy propositions, Fuzzy quantifiers, Linguistic hedges, Approximate reasoning. Fuzzy topologies, F-continuous functions, Fuzzy metric spaces, Fuzzy neighbourhood spaces, Fuzzy convergence, Fuzzy Compact spaces, Fuzzy connectedness, Fuzzy components. Fuzzy substructures of algebraic structures, Fuzzy monoids and automata theory, Fuzzy subgroups and pattern recognition, Free fuzzy monoids and coding theory.

Recommended References

G. J. Klir & U. Clair	: Fuzzy Set Theory.
G. J. Khir & Bo Yuan	: Fuzzy Sets & Fuzzy Logic Theory and Applications.
R. Lowen	: Basic concepts, Techniques and Bibliography.
H.J. Zimmermann	: Fuzzy Sets Theory and Its Applications.

MAT615: Advanced Mathematical Methods 3.00 Credit Hours

Gamma and beta functions: Properties of Gamma function, Continuity and convergence of gamma and beta functions, integral form of gamma of n. Asymptotic representation of Gamma function for Large |n|.

Elliptic integral and elliptic Functions: Reduction of elliptic integrals to standard form, properties of elliptic function addition formulae, periods of elliptic function. The probability integral and related functions.

Orthogonal Sets of Functions: Orthogonal & Normalized Function, weight function, orthonormal set of functions, Strum-Liouville problem, Eigenvalues and Eigenfunctions, Gram-Schmidt process, Parseval's equation.

Laguerre's Equations: Solution, Integral and recurrence formula, Differential forms, Othogonality.

Chebyshev Polynomial: Differential equations, Generating functions, Orthogonality, Recurrence relations.

Legendre functions of the second kind $Q_n(x)$: Associated Legendre's functions. Laplace's first & second integral, Recurrence relations, Christoffel's second summation formula, Newmann's integral.

Bessel Functions: Integral representations, Hankel function, Neumann function. Green's function and its applicantions.

Fourier integral theorem and Fourier transforms: Multiple Fourier transforms, Fourier transforms of radially symmetric functions, The solutions of integral equations of convolution type, Use of Fourier transforms in solving Laplace's equation, diffusion equations and wave equations. The double Laplace transform, the interated Laplace transform, the Stieltjes transform and the Hankel transform. The Perseval relation for Hankel transform and the relation between Fourier and Hankel transforms. Use of Hankel transforms in solving partial differential equations.

Boundary value problems: Wave & Heat equation, Fourier-equation of heat conduction, Separation of variables, Laplace's equation, boundary value problems in polar & cylindrical coordinates, telegraph or transmission line equations.

Hypergeometric Equation: Solution of Hypergeometric function and its properties, Confluent Hyprtgeometric functions, Differentiation, Integral forms and linear transformations of hypergeometric functions, Kummer's function, Gauss function.

Hermite Polynimials: Differential equations, Generating functions, Orthogonality, Recurrence relations, Integral representations, Relation with Legendre Polynomial.

Recommended References

R.V. Churchill	: Fourier Series and Boundary Value Problem
B.D. Gupta	: Mathematical Physics.
Harold Jeffreys & Bertha Swirles	: Methods of Mathematical Physics.
Stephenson	: Mathematical Methods.
M.R. Spiegel	: Fourier and Laplace Transform.

MAT616: Mathematical Modeling and Population Dynamics 3.00 Credit Hours

Population dynamics: Simple continuous and discrete models, graphical and stability theory of linear and nonlinear differential equations, nonlinear population models, age-dependent population model, two species linear and nonlinear population models, multi-species models, stochastic models of population, spatial model, optimal control of population model.
Stochastic Model: Stochastic linear and nonlinear models of population, spatial model, optimal control of population model.
Microbial population models: Microbial population, Chemostat, growth of microbial populations, stability of the models.
Virus dynamics: Virus, immunity, cells, epidemic models, dynamics of infectious diseases, AIDS/HIV models, dynamics of hepatitis B virus, age-dependent epidemic model, stochastic epidemic model.
Anti-virus drug therapy: Control of an epidemic model, drug therapy, vaccination effects, treatment of HIV, CTL response, and immune responses eliminate infected cell, simplest models of immune response dynamics.
Dynamics with diffusion: Diffusion equation, single and multi-species diffusion models, competition model with diffusion, epidemic model with diffusion, diffusion in artificial kidney.
Applications: Blood pressure and its measurements, glucose concentration in blood, heart function test, and optimization models for blood testing.

Recommended References

J.D. Murry	: Mathematical Biology.
J.N. Kapur	: Mathematical Models in Biology and Medicine.
Edward Beltrami	: Mathematics for Dynamic Modeling.
Leah Edelstein-Keshet	: Mathematical Models in Biology.
M.A. Nowak & R.M. May	: Virus Dynamics, Mathematical Principles of Immunology and Virology.

MAT617: Rings and Modules 3.00 Credit Hours

Rings of fractions and embedding theorems. Local rings and Noetherian rings. Rings with ore conditions and related theorems.
Field extensions and finite fields. Wedderburn's theorem on finite dimension rings. Jacobson's work on commutativity condition on division rings. Modules, submodules and direct sums. R-homomorphisms and quotient modules. Completely reducible and free modules. Sequence and exact sequences of modules. Projective and injective modules. Semisimple and simple rings. Artinian and Noetherian modules. Categories and functors, exactness of functors between module categories. Semisimple modules and rings. Radical and socle. The tensor product, flat modules and regular rings. Application of rings and modules to abelian groups, to vector spaces with a linear transformation, to languages, grammars, machines, coding theory etc.

Recommended References

Kenneth S. Miller	: Elements of Modern Abstract Algebra
Hiram Palety and Paul M. Weichsel	: A First Course in Abstract Algebra
O. Zariski and P. Samuel	: Commutative Algebra

MAT618: Graph Theory 3.00 Credit Hours

Introduction: Definition of Graph, Definition types of graphs Application of graphs, Brief history of graph theory.

Paths and circuits: Sub graphs, Walks, Paths, Circuits, Euler graphs, Components, Connected and disconnected graphs, Isomorphism, Puzzle with Multicolored cubes, Hamiltonian paths and circuits, The travelling salesman problem.

Trees and Fundamental circuits: Definition of trees, Properties of trees, Distance and centers in a trees, Rooted and Binary trees, Spanning trees, Fundamental circuits and cut vertices, Cut sets properties of cut sets, Fundamental circuits and cut sets, Connectivity and separability 1-Isomorphism, 2-Isomorphism.

Vector spaces of a Graph: Sets with one and two operations, Modular Arithmetic and Galois fields, Vectors and vector spaces, Vector space associated with a graph, Basis vectors of a graph, Circuit and cut-set subspaces, Orthogonal vectors and spaces, Intersection and join of W_n and W_s.

Matrix Representation of Graphs: Incidence matrix, Sub matrices of A(G), Circuit matrix, Rank and fundamental circuit matrix, Cut set matrix, Relationships among A_f, B_f and C_f path matrix, Adjacent matrix.

Directed graphs: Definition of directed graph, Types of directed graph, Digraph and Binary relations, Directed paths and connectedness, Euler digraphs, Fundamental circuits and digraphs Matrices A, B and C of digraphs, Acyclic digraphs and Decylization.

Graphs in switching and coding theory: Contact networks, Analysis of contact networks, Synthesis of contact networks. Sequential switching networks, Unit cube and its graph, Graphs in coding theory.

Electrical networks analysis by graph theory: Definition of electrical network, Kirehhoffies current and voltage laws, Loop currents and node voltages, R.LC networks with independent sources, Nodal analysis, RLC networks with independent sources loop analysis. General lumped, linear, Fixed networks.

Recommended References

C. Berge	: The theory of Graphs.
F. Harary	: Graph Theory.
K. R. Parthasarathy	: Basic Graph Theory.
Narsingh Deo	: Graph Theory.
Doughlas B West	: Graph Theory.

MAT619: Advanced Number Theory 3.00 Credit Hours

Quadratic residuacity: Quadratic residues and nonresidues, Euler criterion, Legendre symbol. Gauss's lemma, law of quadratic reciprocity, Jacobi's symbol.

Average orders of arithmetic functions: Lim sup, Lim inf, average orders of the arithmetical functions.

Distribution of prime numbers: Bertrand's postulate, Chebyshcvs theorem, the function *Q(x)* and *y/(x)*. The prime number theory; elementary proof via Selberg's lemma, complex analytical proof.

Primes in arithmetic progressions: Characters of an Abelian group, L-functions, Dirichlet's proof of infinitude of primes in arithmetic progressions.

Algebraic number theory: Noetherian rings and Dedekind domains, ideal classes and the unit theorem, units in real quadratic field.

Recommended References

G.H. Hardy and M. Whyle : An introduction to the theory of numbers.
S. Rose : A course in number theory.
P. Samuel : Theory of algebraic numbers.

MAT620: Real Function Theory 3.00 Credit Hours

Algebra, Sigma Algebra, Cantor and Borel sets, Concept of measure, Properties of measure, outter measure, Lebesgue measure, Lebesgue's Monotone convergence theorem, Fatou's Lemma, Lebesgue's dominated convergence theorem, measurable set and functions, Integration of simple and complex functions, Reisz Representation theorem, Basic topological properties of Euclidean spaces, Covering theorems, Regularity properties of functions.

Classical Banach spaces: L^p spaces, Convex functions and inequalities, Conjugate exponents, Minkowski and Holder inequalities, completeness of L^p spaces, approximation and density in L^p, Bounded linear functions on L^p spaces.

Hilbert space: Inner product and linear functional, the triangle inequality, parallelogram low, Bessel's inequality, approximation problems. Abstract measure and integration, measure spaces and measurable functions, integration, signed measures, the Radon-Nikodym theorem.

Recommended References

Paul Halmos : Measure theory
W. Rudin : Real and Complex Analysis
B. K. Lahiri : Functional Analysis
Royden : Mathematical Analysis
Apostal : Mathematical Analysis

MAT621: General Algebraic Topology 3.00 Credit Hours

Basic topological concepts: bases and subbases, subspaccs, continuous maps, weak and strong topologies, quotient spaces. Product spaces.

Convergence: nets and filters. Separation axioms, regular spaces, completely regular spaces, Normal spaces, Urysohm's lemma, Characterization of Normality. Countability properties. Compact and Locally compact spaces, compactification, Metrization, Baire theorem.

Connected spaces: Pathwise and local connectedness. Uniform spaces, uniformizability and uniform metrizability.

Function spaces: Pointwise and uniform convergence, compact open topology. Commutative Topological Groups, Elementary considerations, Bases. Subgroups and Quotient groups, completion of topological groups. Continuous homomorphisms, Groups of functions. Uniformities and metrization.

Recommended References

George F. Simmons : Introduction to Topology and Modern Analysis.
J. L. Kelley : General Topology.

J. P. May : A Concise Course in Algebraic Topology
Allen Hacher : Algebraic Topology

MAT622: Functional Analysis 3.00 Credit Hours

Topological Linear Spaces: Convex lets and hyper planes, semi norms, locally convex spaces, weak topology, compact convex sets, duality in Banach space.
Linear Operators: Continuity and boundedness, fundamental properties of bounded operators uniform boundedness principle, conjugate of bounded linear operators, adjoint operator and its duality, bounded linear operators in Hilbert spaces, unbounded linear operator.
Spectral Analysis of Linear Operators: Spectrum and the resolvent operator, spectrum of a bounded linear operator, compact operators.

Spectral Analysis in Hilbert spaces: Bilinear and quadratic forms, symmetric operators. Normal and self-adjoint operators, the spectral theorem for bounded self-adjoint operators, unbounded self-adjoint operators.

Nonlinear Compact Operators and Monotonicity: Banach Fixed point theorem with applications, Schauder fixed point theorem, Frechet derivative. Newton's method for nonlinear operators, positive and monotone operators.

Recommended References

A.E. Taylor : Introduction to Functional analysis
V. Hutson and J.S. Pym : Applications of Functional analysis and Operator Theory.
Walter Rudin : Functional Analysis.
N. Dunford and J. Schwartz : Linear operators General Theory.

MAT623: Partial Differential Equations (PDEs) 3.00 Credit Hours

Classification of PDE (parabolic, elliptic, hyperbolic), Existence, uniqueness and represention of solutions for the PDE (wave equation & heat equation). Cauchy, Dirichlet and Neumann boundary-value problems for the Laplace and Poisson equation. Potential theory in two and higher dimensional domains, initial and boundary value problems of heat equation and wave equation, Maximum principle of parabolic equation; Sturm-Liouville systems, boundary and eigenvalue problems, method of eigenfunction expansions.

Recommended References

F. Ayres : Differential Equations.
R. Dennemeyer : Introduction to Partial Differential Equations.
M. L. Khanna : Partial Differential Equations.
B. D. Sharma : Partial Differential Equations.
Tyn Myint- U : Partial Differential Equations for scientists and engineers.

MAT624: Biomathematics 3.00 Credit Hours

Blood flows: Concepts of fluid dynamics, Concepts about blood, Cardiovascular system, and Blood flows, Viscosity and Reynolds number of blood flows, Rheological behavior of blood, Steady non-Newtonian fluid flows in circular tube, Newtonian pulsatile flows in rigid and elastic tubes, Blood flow through artery with mild stenosis.

Magnetohydrodynamic: Concepts of Magnetohydrodynamics one dimensional Magnetohydrodynamics equation, The momentum equation, The equation of motion of moving media, The equation of motion of a conducting media, Interaction between flow field and Magnetic field. The magnetic Reynolds number, Alfven's theorem, Alfen's waves, Application of the equation of motion to blood flow. Hartmann flow, Couette and Poiseuille flows, Application to blood flow.

Epidemic models: Differential equations in the theory of epidemics, Deterministic models with and without removal, Control of an epidemic, stochastic models and the dynamics of inflections diseases.

Diffusion and diffusion-reaction models: Diffusion equation in artificial kidney, Oxygen diffusion through living tissues, Diffusion through membrane, epidemic model with diffusions.

Applications: Blood pressure and its measurements, models for gas exchange and air flow in lungs. Glucose concentration in blood, Arterial pulse, Human Erythrocytes from plasma, A heart function test, Physical interpretation of heal function, Nervous excitation, Birth and death processes, Optimization models for blood testing.

Recommended References

Y. C. Fung	: Biomechanics
J. N. Kapur	: Mathematical Models in Biology and Medicine.
J. D. Murray	: Mathematical Biology.
J. G. Defares	: The Mathematics of Medicine and Biology.
R. N. Roy	: A text book of Biophysics.
V. C. Ferraro and C. Plumpton	: An Introduction to Magneto Fluid Mechanics.

MAT625: Industrial Mathematics 3.00 Credit Hours

Statistical reasoning: Random variables, Uniform distributions, Gaussian distributions, the binomial distribution, The Poisson distribution.

Data acquisition and manipulation: The z-transformation, linear recursions, Filters, Stability, Polar and Bode plots, Aliasing, Closing the loop.

The discrete fourier transform: Real time processing, Properties of DFT, Filter design, the fast Fourier transform, Image processing.

Frequency domain method: The frequency domain, Generalized signals, Plants in cascade Surge impedance, Stability, Dilters, Feedback and root-locus, Nyquist analysis, Control.

Microeconomics: Supply and demands, Revenue, Cost and profit, Elasticity of Demand, Duopolistic competition, Theory of production.

Ordinary differential equations: Separation of variables, Mechanics, Linear and non-linear ODEs System.

Partial differential equations: Lumped versus distributed, The big six PDEs, Separation of variables, Unbounded spatial domains, Periodic steady state, Other distributed model.

Monte Carlo methods: Computing integrals, Mean time between failure, Servicing requests, The newsboy problem.

Galerkin's method: Galerkin's requirement, Eigenvalue problems, Steady problems, Transient problems, Finite elements.

Recommended References

Charles R. MacCluer	**:** Industrial Mathematics
Avner Friedman and Walter Littman	**:** Industrial Mathematics

MAT626: Computational Stellar Astrophysics 3.00 Credit Hours

The Solar System: Two-body orbital motion, application to detection of other planetary system, restricted three-body problem. Theories for the origin of the solar system. The 3-body problem, Lagrangian equilibrium points, effects of drag forces, theories of tides, the distributing functions & Perturbations.

Stellar structure & Evolution: Observational Properties of stars, H-R diagram, main sequence, giants and white dwarfs. Properties of stellar interiors, radiative transfer, equation of Stellar, Nuclear reactions, Convection. Models of the sun.

The Stellar Galaxy: The interstellar medium & galactic structure and dynamics. Physical and Chemical Characteristics of gas and dust components, influence on star formation. Excitation of ISM, Collapse of ISM to stars.

Recommended References

Baidyanath Basu	: An Introduction to Astrophysics
Bohm-Vitense	: Stellar-Astrophysics
M Schwarzschild	: Stellar Structure and Evolution

MAT627: Dynamical Systems 3.00 Credit Hours

Basic concepts: Basic definitions & examples. Phase space, phase portrait, discrete dynamics, continuous dynamics, topological dynamics, ergodic theory, topological conjugacy, fixed and periodic points, graphical analysis, iteration, hyperbolic points, hyperbolic dynamics.
Chaotic dynamical systems: Definitions of chaos, sensitive dependence on initial conditions, period three theorem, orbit structure, Cantor set, basin of attractor & repellor, strange attractor and Lyapunov exponents.
Discrete dynamical systems: One parameter family of maps, contractions & fixed point theorem, stability of fixed points, family of logistic map, tent map, doubling map, linear maps, iterative map, quadratic family of maps, small horseshoe map, expanding map.
Differential dynamical systems: One & two dimensional linear & nonlinear differential equations, sinks, source & saddles, stability, population models, Lotka-Volterra models, Henon map, Lorenz map, hyperbolic fixed point, manifold and sub-manifold, stable and unstable manifold, stable manifold theorem, Hartman-Grohman theorem, Hadamard-Perron theorem, Smale theorem.
Bifurcations: Bifurcations, bifurcations points, bifurcations of quadratic maps, saddle-node, period doubling, pitchfork, transcritical bifurcation, bifurcation diagram.
Symbolic dynamical systems: Sequence spaces, shit map, properties of shift maps, symbolic dynamics, itinerary, sub shift of finite type.
Fractals: The chaos game. Cantor set revisited. Sierpinski triangle, Koch snowflake, topological dimension, fractal dimension.

Recommended References

A. Katok and B. Hasselblatt	: Introduction to modern theory of dynamical systems.
R.L. Devaney	: A First course in chaotic dynamical systems
R.A. Holmgren	: A first course in discrete dynamical systems

MAT628: Operations Management 3.00 Credit Hours

Introduction: Introduction to Operations Management, The scope of OM, OM and decision making, Productivity, Product mix, Strategy, Competitiveness.
Capacity Planning: Strategic capacity decision, Strategy formulation, Definition and measuring capacity, evaluating capacity alternatives.
Quality Control: Management of quality, Statistical process control, Variations and control, Control Charts. Process capability, Improving process capability, Capability analysis.
Forecasting: Features common to all forecasts, Elements of good forecast, Steps in the forecasting process, Accuracy and control of forecasting, Applications of Forecasting models.
Inventory Control: Nature and important of inventories. Introduction to basic inventory models, Economic order quantity (EOQ) model, EPQ model. Fixed order interval model, Single period model.
Scheduling: Scheduling in high-volume system, intermediate-volume system, low-volume system, Scheduling methods of Linear Programming Scheduling jobs through two work centers, Minimizing scheduling difficulties, scheduling the work force.
Simulation: Basic terminology of simulation, steps in simulation process, Application of simulation, Simulation with random variables, Advantage and limitations of using simulations
Project Management: Behavioral aspect of project management, Key decisions in project management, Pert(program evaluation and review technique), CPM(critical path method), Deterministic time estimates, Probabilistic time estimate, Applications.

Recommended References

William. J. Stevenson	: Operations Management
Wayne L. Winston	: Operations Research
Hiller and Lieberman	: Introduction OR

MAT629: Riemannian Geometry 3.00 Credit Hours

Introduction: Fundamental notions, Non-Euclidean geometry, symmetric spaces, Riemannian manifolds, Riemannian submanifolds, Pseudo-Riemannian manifolds.
Curvature of Riemannian manifolds: Einstein space, Constant Riemannian curvature. Riemannian curvature, Recurrent space, Ricci-recurrent space, Geodesic curvature, scalar curvature, sectional curvature, Ricci curvature, Ricci decomposition, Weyl curvature, conformal curvature tensor and Einstein manifolds.
Smooth Manifolds: Functions on smooth manifolds. Pull-back of function, Tangent vector and tangent space, push-forward of tangent vectors, smooth vector fields, Lie brackets (communtator). Lie algebra, Examples of matrix groups.
Bundles: Vector bundles, Fibre bundles. Principals bundles. Tangent bundles. Cotangent bundles, Line bundle, Jet bundles, Tensor bundles, dual and normal bundles, subbundles. Vector bundle morphisms and isomorphisms.
Metrics and Connections: Metrics and connections on bundles, Riemannian metrics, Affine connection, torsion and curvature tensors. Parallel transport. Geodesies, Levi-Civita connection, Coordinate representation of the curvature tensor.
Exterior Differential Calculus: Differential form, Exterior derivatives, exterior algebra (Grassman algebra), Grassman manifolds, projective space, the exterior derivative in calculus, wedge product, Poincare' s Lemma.

Symplectic Geometry: Symplectic topology, Symplectic Space, symplectic manifolds, Symplectic structure, Symplectomorphism, Darboux theorem on symplectic manifold and related theorems on symplectic manifolds.

Contact Ceometry: Contact structure, Contact space manifolds, Durboux theorem on contact manifold, complex manifolds, complex projective space, theorem on complex contact manifolds.

Recommended References

C. S. Isham : Modern Differential Geometry

V. I. Arnold : Mathematical Methods of Classical Mechanics

R. W. R. Darling : Differential Forms and Connections

R.O. Wells Jr. : Differential Analysis on Complex Manifolds

Syllabus
of

Master of Science (M. Sc.) in Mathematics
(2-Years Program)

Introduction

The 2- year M. Sc. program in Mathematics offers high quality education and elevates the knowledge in the arena of Mathematics. It prepares the students to meet the challenges and the needs of 21st century. The courses in the syllabus are well designed to enable the students in learning achievement of Mathematics.

In order to obtain M. Sc. Degree in Mathematics, a student will have to study for one year in 2 Semesters. The student will have to complete 69 credits to earn the degree. Teaching for 12 hours is equivalent to 1 credit hour and will be treated as 1 credit. Each 3 credits course is a full unit course which requires contact hours: 36 $(\mathbf{3 \times 12})$. For such a course, there should be effective 36 classes - each of 01 (one) hour duration.

Academic System

Hamdard University Bangladesh follows a model of higher education which consisting of courses, semesters, credit hours, continuous evaluation and letter grading. In keeping with its mission and vision Hamdard University Bangladesh strives to ensure high academic standards by implementing well-designed curricula, selecting quality students and faculty carefully, utilizing modern and effective instructional methods and monitoring continuously with rigorous evaluation of all the pertinent activities.

Requirement for Admission for an Applicant

Those who have secured 45% marks/ Grade C+ (CGPA/GPA 2.50) in the B.Sc. (Pass) with Mathematics are eligible to apply for admission. After admission test, a merit list will be prepared. Then the selected students will be eligible for the admission.

Year 1: M. Sc. (Preliminary) in Mathematics

The course, extension normally over one academic year, is conducted according to the rules of the University. This option is restricted to regular College students who have secured an average of 45% marks in the B.Sc. (Pass) with Mathematics. They are completed 01 year courses with Honors Courses.

The distribution of marks for this option

9 Theoretical Unit Courses	27 Credits
General Viva-voce Examination	03 Credits
Comprehensive Examination	03 Credits
Total:	**33 Credits**

Year 2: M. Sc. (Final) in Mathematics

Courses leading to the degree of M. Sc. in Mathematics will extend over one academic year, is conducted according to the rules of the University. In this year, each **s**tudent is required to study any ten (10) courses [each course 03 Credits carried 100 marks] and get examined as follows:

The distribution of marks for this option

10 Theoretical unit courses$(\mathbf{3 \times 10})$	30 Credits
General Viva-voce Examination	03 Credits
Comprehensive Examination	03 Credits
Total:	**36 Credits**

Program and Semester Duration

The Hamdard University Bangladesh would confer the Degree of M. Sc. in Mathematics after a student has completed satisfactorily all the required courses which are offered over a maximum period of four academic years. The academic year is divided into two semesters.

The breakdown of these semesters is as follows

Classes	20 weeks
Midterm Examination	02 week
Preparatory Leave	01 week
Semester Final Examination	02 week
Total:	**25 weeks**

Evaluation Policy

Every course will be supplemented by assignments, and marks will be allotted for the assignment. Marks will be in whole number; no fractional marks can be given. The distribution of marks for a course will be as follows:

Attendance	5%
Class test	10%
Assignment & Presentation	10%
Midterm Examination	25%
Final Examination	50%
Total:	**100%**

Grading System

The grades at the university will be indicated in the following manner

Numerical Grade	Letter grade	Grade Point
80 % - 100%	A+	4.00
75 % - < 80%	A	3.75
70 % - < 75 %	A-	3.50
65 % - < 70 %	B+	3.25
60 % - < 65 %	B	3.00
55 % - < 60 %	B-	2.75
50% - < 55 %	C+	2.50
45 % - < 50 %	C	2.25
40 % - < 45 %	D	2.00
Less than 40%	F	0.00

Grades without numerical value

P **:** Pass
I **:** Incomplete
W **:** Withdrawal

Pass/Fail Option

A course may be taken for a pass/fail grade, providing that the teacher approves the option and the student carries all the credits offered by the Department for regular letter

grades in that semester. A maximum of 18 (eighteen) credits may be taken for credit with the pass/fail grading option. No more than 6 (six) credits may be taken with the pass/fail grading option in any one semester. Departments may not approve the pass/fail grading option for some courses counting towards the major.

Incomplete Grade

An Incomplete I grade is assigned only when a student has failed to complete one or more requirements of the course for unavoidable reason/accidental circumstance and has applied for I grade. The students who are permitted to appear in makeup examination (s) will be assigned an (I) grade for that course and this grade will stay until the student appears in the makeup examination at the first available opportunity; if he/she fails to appear in the makeup examination the (I) grade will automatically be converted to (F) grade.

Withdrawal (W)

The course withdrawal is assigned to a student who withdraws from the course within the deadline for withdrawal with 'W' grade. A student, who withdraws after this date, will earn the grade based on his performance before his withdrawal. Exception to this rule may be made on medical ground and in terms and conditions of the University.

GPA Computation

The Grade Point Average (GPA) is computed in the following manner

$$\text{GPA} = \frac{\sum(\text{Credit Hour} \times \text{Grade Value})}{\sum \text{Credit Hour}}$$

$$\text{CGPA} = \frac{\sum(\text{No. of Credits} \times \text{Grade Value})}{\sum \text{No. of Credits}}$$

Grades Review Procedure

The Academic Council of the University administers the Grading Regulations and reviews course grades submitted by the Departments.

Academic Standing

Students should take the requisite number of courses and maintain satisfactory grades in the courses. They are expected to maintain a GPA of 2.00 (both semester and cumulative); otherwise, they will be put on probation for the following semester. Course grade can be improved in the next available opportunity by paying the applicable course fee. In case of 'F' grade, the student has to take the class in full with all the examinations. Grade 'B-'and below may be improved by the students.

Methods and Medium of Instructions

The university teaching meets the demand of the time adopting present-day teaching methods including interactive internet, simulation, lab work, case analysis and field study. A special feature of teaching at Hamdard University Bangladesh is the

workshop/lab sessions designed to assist students in learning application of concepts (mostly activity- based education) and theories. The medium of instruction in Hamdard University Bangladesh is English.

Program Approval

Any Post Graduate program must receive the signed approval of the BPGS prior to the admission in that program.

Formation of Board of Post Graduate Studies (BPGS)

The Board of Post Graduate Studies (BPGS) would be constituted as follows:

Chairman	Head of Mathematics Department
Member	All teachers of this Department

Eligibility of Faculty Member Conducting the Course

A Faculty member, who would be chosen to conduct courses in M. Sc. in Mathematics program, must have at least one postgraduate degree.

M. Sc. (Preliminary) Course Title

Course Code	Course Title	Credits
MAT451	Theory of Numbers	3 Credits
MAT452	Discrete Mathematics	3 Credits
MAT453	Vector and Tensors Analysis	3 Credits
MAT454	Mathematical Methods-I	3 Credits
MAT455	Real Analysis	3 Credits
MAT456	Partial Differential Equations	3 Credits
MAT457	Mechanics	3 Credits
MAT458	Numerical Analysis	3 Credits
MAT459	Abstract Algebra	3 Credits
MAT460	Linear Programming	3 Credits
MAT461	Hydrodynamics	3 Credits
MAT462	Differential Geometry	3 Credits
MAT463	Mathematical Modeling in Biology	3 Credits
MAT464	Astronomy	3 Credits
MAT465	Integral Equations	3 Credits
MAT466	Mathematical Methods-II	3 Credits
MAT467	Fuzzy Mathematics	3 Credits
MAT498	Viva Voce Examination	3 Credits
MAT499	Comprehensive Examination	3 Credits

M. Sc. (Final) Course Title

Course Code	Course Title	Credits
MAT601	Numerical Methods for Differential Equations	3 Credits
MAT602	Operations Research	3 Credits
MAT603	Magnetohydrodynamics	3 Credits
MAT604	Aerodynamics	3 Credits

MAT605	Fluid dynamics	3 Credits
MAT606	Differential and Integral Equations	3 Credits
MAT607	Quantum Mechanics	3 Credits
MAT608	Asymptotic and Perturbation Methods	3 Credits
MAT609	Similarity Analysis	3 Credits
MAT610	Computational Fluid dynamics and Heat Transfer	3 Credits
MAT611	Geometry of Differential Manifolds	3 Credits
MAT612	Theory of Relativity	3 Credits
MAT613	Lattice Theory	3 Credits
MAT614	Fuzzy Mathematical Structures	3 Credits
MAT615	Advanced Mathematical Methods	3 Credits
MAT616	Mathematical Modeling and Population Dynamics	3 Credits
MAT617	Rings and Modules	3 Credits
MAT618	Graph Theory	3 Credits
MAT619	Advanced Number Theory	3 Credits
MAT620	Real Function Theory	3 Credits
MAT621	General Algebraic Topology	3 Credits
MAT622	Functional Analysis	3 Credits
MAT623	Partial Differential Equations	3 Credits
MAT624	Biomathematics	3 Credits
MAT625	Industrial Mathematics	3 Credits
MAT626	Computational Stellar Astrophysics	3 Credits
MAT627	Dynamical Systems	3 Credits
MAT628	Operations Management	3 Credits
MAT629	Riemannian Geometry	3 Credits
MAT697	Viva Voce Examination	3 Credits
MAT698	Comprehensive Examination	3 Credits

M. Sc. (Preliminary) Course Detailed Syllabus

MAT451: Theory of Numbers 3.00 Credit Hours

Basic concepts: Mathematical Induction. The Binomial theorem, Prime number theorem Divisibility Theory: The division Algorithm, The greatest common divisor, The Euclidean Algorithm, The Diophantine equation.

Primes and their Distribution: The Fundamental theorem of Arithmetic, The sieve of Eratosthenes, The Goldbach conjecture.

The theory of Congruence: Basic concepts, Basic properties of congruence, Special Divisibility tests, linear congruence.

Factorization Method: Fermat's theorem, Fermat's factorization method. The little theorem, Wilson's theorem, Fermat's last theorem (statement).

Number theoretic Functions: The functions τ and σ, The mobius inversion formula, The greatest integer function.

Euler's Generalization of Fermat's Theorem: Euler's phi-Function Euler`s theorem, properties of the phi- Function, An application to cryptography, Fibonacci Numbers and continued fractions: The Fibonacci sequence, Fibonacci numbers, Finite continued fractions Infinite continued fractions.

Recommended References

G.H. Hardy and E.M Wright	: An Introduction to the Number Theory.
W.J. Leveque	: Fundamentals of Number theory.
W.J. Leveque	: Topics in Number Theory.
David M Burton	: Topics in Number Theory.

MAT452: Discrete Mathematics 3.00 Credit Hours

Propositions, Relations and Functions: Propositions, A relation model for data bank, Properties of binary relations, Equivalence relations and Partitions, Partial ordering, relations and Lattices, chains and anti-chains, Functions on finite sets, Euler's Function, Designs, t-designs and Pigeonhole principle.
Trees and cut sets: Trees, rooted trees, Path lengths in rooted trees, Binary search trees, spanning trees and cut sets, Minimum spanning trees.
Boolean Algebra: Lattices and Algebraic systems, Principle of duality, Basic properties of algebraic system defined by lattices, Distributive and complemented Lattices, Boolean, Lattices and Boolean algebras, Boolean functions and Boolean expressions.
Finite Geometries: Finite fields, Finite geometry and Designs, Finite Projective planes.

Recommended References

R.S Aggarwal & R.S Matharu	: A Text book of Discrete Mathematics 1993
N. L Biggs	: Discrete Mathematics
P. J Cameron &J. H Van Kint	: Graph Theory, Coding Theory and Block Designs
C. L Liu	: Elements of Discrete Mathematics.
J. Robert & McElice	: Introduction to Discrete Mathematics.
Rosen	: Discrete Mathematics.

MAT453: Vector and Tensor Analysis 3.00 Credit Hours

Vector Algebra: Definition of vector, Addition and subtraction of vectors, Dot and cross product of vectors,Vector applications to geometry and mechanics, Vector triple and multiple products. Definition of line, surface and volume integrals.
Vector Calculus: Differentiation of vectors with application, Gradient of a scalar function, Divergence and curl of a vectorfunction, Physical signification of gradient, divergence and curl.
Integral forms of Gradient, Divergence and Curl, Vector integration, Independent of path, Green's theorem, Gauss's divergence theorem, Stokes theorem and their applications. Curvilinear coordinates.
Kronecker delta, Summation convention,Space of N-dimensions, Euclidean and Riemannian space, Coordinate transformation, Contravariant and covariant vectors, The tensor concept, symmetric and skew-symmetric tensor.
Riemannian metric and metric tensors: Basis and reciprocal basis vectors, Euclidean metric in three dimensions, Reciprocal or conjugate tensors, Conjugate metric tensor, Associated vectors and tensor's length and angle between two vectors, The Christoffel symbols, Transformation laws of Christoffel symbols.
Geodesic,Covariant Differentiation of tensors and applications: Covariant derivatives and its higher rank tensors, Physical components of a tensor, The intrinsic derivative, The Riemann-Christoffel tensor and covariant curvature tensor, Bianci identity.

Recommended References

M.R Spiegel	: Vector Analysis and Introduction to Tensor Analysis

B Spain	: Tensor Calculus.
D.C. Augerwall	: Tensor Calculus
Lauden	: A introduction to Tensor Calculus.
I.S. Sokolnikoff	: Tensor Analysis
Willey Aris.	: Vector and Tensor.

MAT454: Mathematical Methods I 3.00 Credit Hours

Fourier series: Definition, Fourier coefficients, sine and cosine series, Drichlet's condition, properties and applications.
Fourier Integral: Definition, Different forms of Fourier integral theorem, Fourier integral formula, Fourier integral of functions.
Fourier transforms: Fourier sine and cosine transforms, complex Fourier transform, Fourier integral theorem, convolution theorem, applications to boundary value problems related to PDE.
Eigenvalues ans Eigenfunctions: Orthogonal and orthonormal set of functions, Strum-Liouville problem, Boundary value problem.Green's function.
Laplace transforms: Definition, Existence and basic properties, Inverse Laplace Transform and convolution, Evaluation of integrals, Solution of linear differential equations with constant coefficients and linear systems, Applications to boundary value problems related to PDE.
Harmonic analysis: Solutions of Laplace equations in Cartesian, Cylindrical and Spherical coordinates.

Recommended References

R.V Churchil	: Fourier series and Boundary Value Problem.
B.D. Gupta	: Mathematical Physics.
Jeffreys and Jeffreys	: Methods of Mathematical Physics.
Stephenson	: Mathematical Methods.
M.R Spiegel	: Fourier and Laplace Transform.
M.D. Raisinghania	: Laplace & Fourier Transform.

MAT455: Real Analysis 3.00 Credit Hours

Real number system: The completeness axioms and Dedekind's axioms. Limit points of a set of real numbers, Bolzano-Weierstrass theorem.
Sequence of real numbers: Definition, convergence of a sequence, subsequence, and monotonic sequence bounded sequence, Cauchy sequence, Cauchy criteria for convergence of sequences.
Infinite series: Concept of sum and convergence, series of positive terms, alternating series, absolute and conditional convergence, tests for convergence.
Functions: Limits and continuity of functions with their properties, uniform continuity, Heine-Borel theorem, differentiability of functions, Rolle's theorem, Intermediate value theorem, Mean value theorem, Taylor's theorem with remainder in Lagrange's and Cauchy's forms, expansions of functions.
Power series: Interval and radius of convergence, differentiation and integration of power series, Abel's continuity theorem.
Riemann integrals: Definition of Riemann integration, Riemann integration with related theorems, Darboux theorem, conditions for integrability, fundamental theorem and mean value theorem of integral calculus, Riemann-Stieltjes integrals.

Recommended References

W Rudin	: Principle of mathematical analysis
I. Apostol	: Mathematical Analysis
Bartle	: Real Analysis
J. G Burkill	: A First Course in Mathematical Analysis

MAT456: Partial differential equations 3.00 Credit Hours

First order equations: Partial differential equations, linear partial equation of order one, Lagrange form, complete integral. General solution. Cauchy problems. Method of characteristics for linear and quasi-linear equations. Charpit's method for finding complete integrals. Methods for finding general solutions.
Second order equations: Classifications. Reduction to canonical forms. Characteristic curves. Boundary value problems related to linear equations.
Applications of Fourier methods (Coordinate systems and seperability. Homogeneous equations. Non-homogeneous boundary conditions. Inhomogeneous equations.) Problems involving cylindrical and spherical symmetry. Boundary value problems involving special functions. Transform methods for boundary value problems (applications of the Laplace transforms; applications of Fourier sine and cosine transforms). Inhomogeneous equations.

Recommended References

H.T.H. Piaggio	: Differential Equations
B. Epsteim	: Partial Differential Equations
I.N.Sneddon	: Introduction to Partial Differential Equations
J.M. Kar	: Partial Differential Equations

MAT457: Mechanics 3.00 Credit Hours

General conditions of equilibrium, Principle of virtual work, Stable and unstable equilibrium, Center of gravity. Rectilinear motion, Motion in a plane, Motion of a particle under a central force, Motion of a particle in space, Motion of rigid bodies, Moment of inertia, D' Alembert's principle, Motion about fixed axes.

Recommended References

F Chorlton	: Text book of Dynamics.
S.L Loney	: Statics.
S.L Loney	: Dynamics of a Particle and of Rigid bodies.
A.S Ramsey	: Statics.
A.S Ramsey	: Dynamics. (Vol-I & II)

MAT458: Numerical Analysis 3.00 Credit Hours

Solution of Equation in one variable: Bisection algorithm, Method of false position, Fixed point iteration, Newton Raphson Method, Error Analysis for iterative method, Accelerating limit of convergence.
Interpolation and polynomial approximation: Taylor Polynomials, Interpolation and Lagrange polynomial, Iterated interpolation, Extrapolation.
Differentiation and Integration: Numerical differentiation (Three points-Five points formula for finding derivatives), Richardson's extrapolation, Elements of Numerical

Integration, Trapezoidal rule, Simpson's rule, Composite Numerical Integration, Adaptive Quadrature method, Romberg's integration, Gaussian quadrature.
Solutions of linear systems: Cramer's rule, Gaussion elimination and backward substitution, Gauss-Seidal method, Linear algebra and Matrix inversion, Determinant of a matrix, Pivoting strategies, Direct factorization of matrices.
Iterative technique of Matrix algebra: Iterative techniques for solving linear systems, LU-Decomposition, Error estimates and Eigenvectors.
Numerical solution of Non-linear system: Fixed point for functions of several variables, Newton's method, Quasi-Newton's method.
Initial value problem for O.D.E: Euler's method, Higher order Taylor's methods, Runge-Kutta methods, Multi-step methods, Variable stepsize multistep methods, Extrapolation method.
Boundary value problem: Linear shooting method, Shooting method for non-linear BVP

Recommended References

A. R Bashishtha	: Numerical Analysis
J.D Burden and Faires	: Numerical Analysis
S.S Kuo	: Numerical methods and computers
Scarborough	: Numerical Mathematical Analysis
S Shastrey	: Introductory Methods of Numerical Analysis

MAT459: Abstract Algebra 3.00 Credit Hours

Groups: Binary relation, Semi group,Group, Subgroups, Definition, Identity, Inverse and order of an element of a subgroup, Criteria of a subgroup, Union of a subgroup and related theorems, Cosets, Lagrange's theorem, Order of an element of a group, Cyclic groups, Permutation groups, Symmetric groups, Alternative groups, Homomorphism and isomorphism of group, Automorphism.
Normal subgroups: Definition, different characteristics, Quotient groups,Kernel of homomorphism, Fundamental Theorem of homomorphism, Hamiltonian groups, Normalism of subgroups, Quotient groups, Conjugacy, The class equation, Direct product, Groups of small order.
Rings, ideals and Integral domains: Rings, Various types of rings, Properties of rings, Characteristics of a ring, Ideals, Quotient rings, Principal ideal, Principal ideal ring, Prime and maximal ideals, Integral domain, Homomorphism and isomorphism of rings.
Factorization in Integral domain: Divisibility, Units, Associates, H.C.F, L.C.M, Polynomial rings, Primitive polynomials (Gauss's theorem), Eisenstein's irreducibility criterion, Euclidean domain, Uniqueness of factorization.
Fields: Characteristics, Subfields, Prime fields, Finite fields.

Recommended References

R.S Aggarwal	: Modern Algebra
R. Balakrishan	: A Text book of Modern Algebra
R. A. Dean	: Elements of Abstract algebra
I.N Herstein	: Topics in Algebra
M.L Khanna	: Abstract Algebra.
H Paley & P.M. Weicheel	: A first course in Abstract Algebra

MAT460: Linear Programming 3.00 Credit Hours

Basic Concepts, Convex sets and related theorems.
Introduction to Linear programming: Formulations and Graphical solutions of system of linear inequalities and linear program, Solution of linear programs by simplex algorithm (Simplex method, Two-phase method, Big-M method).
Duality of linear programming and related theorems, Dual simplex method, Sensitivity and Parametric analysis, Transportation Model, Assignment problem.

Recommended References

D.K Gupta	:	Linear programming & Theory of Games
S.I. Gass	:	Linear Programming.
Hardy A. Taha	:	Operation Research.
Hira & Gupta	:	Theory and Problems of Operation Research
J. K Strayer	:	Linear programming & its Application
Luenberger	:	Linear and Nonlinear Programming

MAT461: Hydrodynamics 3.00 Credit Hours

Kinematics of Fluid in motion: Velocity and acceleration of fluid particles, Streamlines and path lines, Steady and unsteady flows, Uniform and non-uniform flows, Velocity potential and vortices vectors, Relation between local and individual time rates, Equation of continuity (Cartesian, Spherical and cylindrical polar coordinates), Acceleration of fluid in motion, Boundary surfaces.
Equation of motion: Pressure, Conditions at a boundary of two Inviscid immiscible fluids, Euler's equation of motion, Bernoulli's equation, Potential theorem, Axially symmetric flows, Impulsive motion, Motion under conservative field of forces, Vortex motion, The energy equation and Kelvin's minimum energy theorem.
Two-dimensional motion: Stream function, Complex velocity and complex potential for 2D flow, Velocity potential, Relation between stream function and velocity potential, Stagnation points, Rotational, Irrotational and incompressible flow.
Sources and sinks: Two-dimensional sources, sinks and doublets, Combination of sources and stream, Source and sink of equal strengths, Complex potential due to source and doublet, The image system, Circulation and vorticity, Circle theorem, Blasius theorem, Motion past a circular and elliptic cylinder, Pressure at a point on a circular cylinder.
Vortex motion: Vortex tube, Strength of a vortex, Vortex pair, Complex potential due to vortex motion, Vortex in or outside a circular cylinder, Vortex rows, Spiral and compound vortex.
Compressible flow theory: Compressibility effects in real fluids, Elements of wave motion (ID- wave equation, wave equations in 2 and 3-D spherical waves, progressive and stationary waves). Speed of sound in gas, Equation of motion in gas, Subsonic, Sonic and Supersonic flows, Isentropic gas flow, Reservoir discharge through a channel, Shock waves.

Recommended References

F. Chorlton	: A Text Book of Fluid Dynamics.
P.P Gupta	: Hydrodynamics.
L.M Milne-Thomson	: Theoretical Hydrodynamics.
Ramsey	: Hydrodynamics.
D. E. Rutherford	: Fluid Dynamics.

MAT462: Differential Geometry 3.00 Credit Hours

Introduction, Curves in space: Space curves, Path, Equivalent paths change of parameter, Arc length, Tangent line contact of nth order of a curve and a surface, Inflectional tangent, Theosculating plane, Osculating plane at the point of inflexion. Tangent at any point of the surface $f(x,y,z)=0$, Normal plane, Principal normal and Binomial, Direction of principal normal and binormal the unit vectors t,n,b Curvature, Torsion and screw curvature, Serret-Frenet formulae, Curvature and torsion of a curve, Helices, Intrinsic equations. Fundamental theorem of space curves, Circle of curvature, Osculating Sphere, Involute and Evolutes the Spherical indicatrix, Bertrand curves.

Defination of surface, Class of surface, Regular and singularities on a surface, Curvilinear equations of the curve on the surface, Parametric curves, Fundamental forms, Two fundamental forms, First fundamental form or metric, Relation between E, f, G and H, Element of area, intrinsic and non–intrinsic properties of a surface, Second fundamental form, Geometric properties of 2^{nd} fundamental form, Derivatives of N, Weingarton Equations, Angle, between parametric curves, Direction coefficients, Families of curves, Orthogonal trajectories, Double family of curves, Envelope, Edge of Regression and Developable, Family of surfaces. Characteristics, Envelope the edge of regression, Developable surface, Geodesic and Mapping on Surfaces, Geodesies Differential equation of geodesics, Properties of geodesics, Geodesic on a surface of revolution, Clauraut`s theorems, Geodesic curvature, Gauss Bonnet theorem.

Recommended References:

S Lipschutz : Differential Geometry.
Struik : Differential Geometry.
D.C. Agarwal : Differential Geometry.

MAT463: Mathematical Modeling in Biology 3.00 Credit Hours

Modeling processes, Nature of mathematical Model, Mathematical modeling through first order ODEs, Mathematical modeling through system of first order ODEs, Mathematical modeling through PDEs.

Mathematical modeling through difference equations, Mathematical modeling through graphs, Mathematical modeling through integral, Delay-differential and differential equations, Mathematical modeling through mathematical programming and maximum principle.

Recommended References

Berry, Burghes : Mathematical Modeling courses
C. Dyson : Principles of Mathematical Modeling
D.N. Burghes : Mathematical modeling in social Management & Life Sciences.
D.N. Burqhes : Mathematical with Differential Equations

MAT464: Astronomy 3.00 Credit Hours

Sphere and spherical triangles and their properties, the celestial sphere, celestial co-ordinates transformation of celestial coordinates, problems connected with Diurnal motion, Astronomical refraction, Retraction planetary motion Time, seasons Finding the latitude of the place. The ecliptic and the first point of Aries.

The solar system, Parallax aberration precession and mutation, Eclipses the solar system. Precession and Nutation, Annual parallax, Aberration of light, The stellar universe, Working process of the Hubble Telescope and its findings.

Recommended References

Datta and Choudhury	: Astronomy
Godtrey	: Spherical trigonometry
J. M. Kar	: Astronomy
Khan and Sikder	: Astronomy
Smart	: Spherical trigonometry
K. K Dee	: Astronomy.

MAT465: Integral Equations 3.00 Credit Hours

Definition of integral equations and their classification, Differentiation under an integral sign, Relation between differential and integral equations, Solution of Volterra and fredholm integral equations of first and second kind.
Method of successive approximations, integral schemed for fredholm integral equations of the second kind, Resolvent kennel, Application of iterative scheme to Volterra internal equations of the second kind, Fredholm's theory: Fredholm's first second and third theorem.
Degenerate kernels, Approximation by degenerate kernels, Fundamental properties of eigenvalues and eigenfunctions.
Hilbert Schmidt theory: Symmetric Kernel, Orthogonal & Normalized system of functions, Hilbert Schmidt theorem, Green's function, construction of Green's function, integral equations & Green's function for BVPs. Singular integral equations, Abel integral equation Cauchy type integral equation, Poincare -Bertrand formula, Hilbert kernel &Helbert formula, Solution of Hilbert type singular integral equations of first and second kind.

Recommended References

Willam vernm Lovitt	:LinearIntegral Equations.
Shanti Swarup	:Integral Equations
M.D. Raishinghania	: Linear Integral Equations
S.G. Michelins	: Integral Equations
R.P. Kanwal	: Linear Integral Equations.

MAT466: Mathematical Methods II 3.00 Credit Hours

Associate Legendre polynomials, Bessel function of Second kind and Third kind, Associate Hermite and Laguerre polynomials, Green's theorem and its applications, Solution of homogeneous and non-homogeneous differential equations, Orthogonal set of functions, Orthogonal set of complex functions, The adjoint equation and self adjoint equations, Sturm Liouvilles theorem, Error function.
Laplace Integral, Lerch's theorem, Laplace transform of Dirac-delta function, Fourier Integral theorem, Inversion theorem for Fourier transform, Mellin transform, Hankel Transform, The Infinite Hankel transform, The Finite Hankel transform, Z- Transform.

Recommended References

A Nohet	: Ordinary Differential Equation.
Rajputh	: Mathematical Physics.
Goyal and Gupta	: Integral Transform.

Sharma and Gupta : Mathematical Methods.
Md. Abdur Rahman : College Mathematical Methods

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MAT467: Fuzzy Mathematics 3.00 Credit Hours

Crisp sets and fuzzy sets: An overview of crisps sets; the notion of fuzzy sets; basic concepts of fuzzy sets. An overview of classical logic;
fuzzy logic: Operations of fuzzy sets; General discussion; fuzzy complement; fuzzy union; fuzzy intersection combinations of operations ; general aggregation operations.
Fuzzy arithmetic: fuzzy numbers, linguistic variables, arithmetic operations on intervals and fuzzy numbers, lattice of fuzzy numbers, fuzzy equations.
Fuzzy relations : Crisp and fuzzy relations ; binary relations on a set; equivalence and similarity relations; compatibility or tolerance relations; orderings; morphisms; fuzzy relational equations.

Recommended References

G. J. Klir & U. Clair : Fuzzy Set Theory.
G. J. Khir & Bo Yuan : Fuzzy Sets & Fuzzy Logic Theory and Applications.
R. Lowen : Basic concepts, Techniques and Bibliography.
H.J. Zimmermann : Fuzzy Sets Theory and Its Applications.

M. Sc. Final Course Detailed Syllabus

MAT601: Numerical Methods for Differential Equations 3.00 Credit Hours

Introduction to Finite Element Method (FEM): Discretization, Construction of basic functions. Numerical integration; coordinate transformation, local and global derivatives, mesh generation, h-p convergence, finite element approximation of line and double integrals.
Method of Weighted Residuals: Subdomain, Collocation, Galerkin and Least-Squares methods. Matrix Formulation; Modified Galerkin techniques, Element/ stiffness matrix.
Finite element solution of Boundary Value Problems (BVP): Outline of FE procedures for 1-D and 2-D problems (Poisson's and Laplace's equations), Matrix Formulation, Element concept. Assembly. Triangular, Rectangular and Quadrilateral elements (linear and quadratic elements).
Variational Formulation of BVP: Functional and Variational Calculus. Construction of Functional, Finite Difference Method, Rayleigh Ritz Method and Finite elements**.** Review of Finite difference approximation. Applications to solve eigenvalue problems and higher order BVP.
Elliptic Partial Differential Equations (PDE): Difference equations for Poisson's and Laplace's Equations BVP, matrix formulation, Convergence by iterative methods, and error analysis.
Parabolic Problems: Derivation of difference formulas for IBVP. Matrix formulation. Heat Equation, Forward, Backward and Crank-Nicolson Methods, Difference methods in 2-space dimensions, ADI method. Stability and error analysis.
Hyperbolic Problems: Difference methods for a scalar IVP and IBVP, Lax-Wendroff and Courant-Friedrichs-Lewy explicit methods. Wendroff implicit method, Wave Equation in time dependent and two space dimension. Convergence and stability analysis.

Recommended References

P.E. Lewis and J.P. Ward	: The finite element method; Principles and Application.
O.C. Zienkiewicz and K. Morgan	: Finite Elements and approximations.
M.A. Celia and W.G. Gray	: Numerical Methods for Differential Equations.
G.D. Smith	: Numerical solution of Partial differential equations.
Paul DuChateau and David Zachmann	: Applied Partial Differential Equations.

MAT602: Operation Research 3.00 Credit Hours

Basics of Operations Research: Introduction, Definition. Characteristic. Necessity. Scope, Classification of problems, Types of mathematical models. Review of Linear Programming.
Transportation and Assignment problem: Introduction, Formulation. Relationship with LP, Solution procedure and Applications.
Network Models: Network definitions, Shortest Route problem, Minimal Spanning Tree problem and Maximal-Flow problem.
Integer programming: Introduction. Branch and Bound Algorithm, Cutting-plane Algorithm, Application.
Sequencing Problem: Sequencing problem processing n jobs through two machines, n jobs through three machines, two jobs through m machines, n jobs through m machines and approaches to more complex sequencing problems.

Matrix Game Theory: Introduction. Minimax-maximin pure strategies. Mixed strategies and Expected payoff, solution of 2×2 games, solution (2×n) and (m×2) games, solution of (m×n) games by linear programming and Browns algorithm.
Dynamic Programming: Introduction, Investment Problem, Production scheduling problem. Stagecoach problem, Equipment replacement problem.
Nonlinear Programming: Introduction, Unconstrained problem, Lagrange method for equality constraint problem, Kuhn-Tucker method for inequality constraint problem and Quadratic programming problem.

Recommended References

Hamdy A. Taha	: Operations Research.
Richard Bronson, Govindasami Naadimuthu	: Operations Research.
Anderson, Sweeney, Williams	: An Introduction to Management Science.
W. L. Winston, J. B. Goldberg	: Operations Research.

MAT603: Magnetohydrodynamics 3.00 Credit Hours

Introduction of MHD and its applications: State electromagnetic (Maxwell's) equations, discuss importance for various terms, State fluid equations-discuss mass continuity Navier Stokes and energy equations, MHD Approximation, Magnetic field visuaisation, The Lorentz force pressure and tension, Magnetohydrodynamic balance, Force-free fields.
The Induction Equation: The magnetic induction equation, Non-dimensinalisation and magnetic Reynolds number $R_{m,}$ The diffusive (R_m«l) and perfectly conducting limit (R_m>>1), Alfen's frozen flux theorem, The Bondy Golg Theorem, The Cauchy solution, The induction and diffusion.
Static Magnetic Field: Rayleigh-Benard Convection, Hartman flow, Magnetohydordynamic fields, Plasma containment, Qualitative discussion of stability.
Waves: Linearisation of MHD equations, Modal expansion, Alfven speed, Alfven waves, Acoustic waves, Magnetoacoustic waves.
Dynamo Theory: Definition of dynamo, dynamo conditions, Classification of dynamos, Energetics, Cowlings theorem, Toroidal and Peloidal fields.

Recommended References

P.A. Davidson	: An Introduction to Magnetohydrodynamics
E.R. Pries	: Solar Magnetohydrodynamics
J.A. Shercliff. Pergamon	: A Text Book on Magnetohydrodynamics
R.T. Merill et al.	: The Magnetic field of the Earth: Paleomagnetism
H.K. Mofatt	: Magnetic field generating in electrically conducing.

MAT604: Aerodynamics 3.00 Credit Hours

Preliminary Notions: Aerodynamic force, lift and Drag. Chord of a Profile, Chord of an Airfoil. Aspect ratio, Geometrical incidence / Angel of attack.
Thermodynamic Conception: Thermodynamic Slate. Variables of state, Equation of state, the First Principal law of Thermodynamics, the concept of Entropy, I lie Second law. The Canonical equation of state. Free Energy and Free Enthalpy.

One Dimensional Motion: Continuity, Energy and Momentum Equations, Euler's Equation. Speed of Sound, Mach Number, Normal shock relation. Propagating Shock wave, the Acoustic equations, Propagation of Acoustic waves.
Two-Dimensional Motion: Oblique Shock waves, Supersonic Flow over a wedge, Mach lines: the Prandtl-Meyer function, Reflection of Oblique shocks. Mach reflection.
The General Equation of a Frictionless Flow of a Gas: The Continuity, Momentum and Energy Equations, The Eulerian Derivative. Natural coordinates, Crocco's Theorem.
Small Perturbation Theory: Induced/perturbed velocity. Derivation of the perturbation equations, Pressure coefficient. Boundary conditions. Two Dimensional flow past wave shaped Wall. Wavy wall in subsonic/supersonic flows, Supersonic thin airfoil theory.
Slender Body Theory: Axially symmetric flow, Subsonic and Supersonic flows. Yawed body of revolution in supersonic flow. Cross-Flow, Cross-Flow Boundary Conditions, Cross-Flow Solutions, Slender Bodies of Revolution.
Transonic Flow: Concept of transonic flow. Transonic range, Transonic flow past a wedge sections, the hodograph transformations and applications to nonlinear transonic flow field.
The Method of Characteristics: Hyperbolic equations, The compatibility relation. Axially symmetric flow, Non-isentropic flow, Intersection of waves.

Recommended References

H.W. Liepmann & A.Roshko	: Elements of Gas Dynamics.
L.M. Milne- Thomsen	: Theoretical Aerodynamics.
Shih- I Pai	: Viscous Flow Theory.
W.F. Durand	: Aerodynamic Theory

MAT605: Fluid dynamics 3.00 Credit Hours

Fundamental concepts: Newton's law of viscosity. Newtonian and non-Newtonian fluids. Body and surface forces, Stress and Rate of strain and their relation. Derivation of the Navier-Stokes equations of motion and its general properties.
Some exact solutions of the Navier-Stokes equations: Steady plane flows: Parallel flow through a straight channel and generalized Couettee flows, plane Poiseille flow, Flow through a circular pipe-the Hagen-Poiseulle flow, Flow between two coaxial cylinders, Flow between concentric circular cylinders.
Unsteady plane flows: Flow between two parallel plates, Flow over a suddenly accelerated flat plate, Flow over an oscillating plate.
Small Reynolds number flows: Differential equation of very low motion, Slow motion over a sphere, Hydrodynamic theory of lubrication.
Laminar boundary layer theory: General concepts and properties of boundary layer theory, Prandtl's boundary layer equations, Separation of a boundary layer, Similarity concepts and similarity solutions of the boundary layer equations, Flow in a convergent channel, Flow past a wedge, Boundary layer on a flat plate at zero incidence, Boundary layer flow with pressure gradient, Karman's integral equation, Application of Karman's integral equation (Karman- Pohlhasen method).
Thermal boundary layer in laminar flows: Derivation of the energy equation, Thermal boundary layer simplifications, Forced and Natural flows, Parallel forced flow past a flat plate at zero incidence, Natural flow past a horizontal vertical plates (some specific Problem).
Stability theory (onset of turbulence): Principles of the theory of stability of the laminar flows, Mathematical form of disturbances (Orr-Sommerfeld equation).

Turbulence: Definition of turbulence and its origin, Equations of motion for turbulent flows, Eddy viscosity concept, Prandtl's mixing length hypothesis, Von-Karman's similarity hypothesis.

Recommended References

H. Schlichting	: Boundary Layer Theory
D.J. Acheson	: Fluid Dynamics
I.Pop and D.B. Ingham	: Convective Heat Transfer
S. Kakac and Y.Yener	: Convective Heat Transfer

MAT606: Differential and Integral Equations 3.00 Credit Hours

Existence and uniqueness theorem for differential equations: Methods of successive approximations, Peano's existence theorem, fixed point methods, Continuation of solutions.
System of differential equations: Linear systems and their solutions by eigenvalue methods, variation of parameters, Exponentials with applications.
Integral equations: Conversions of IVP's to integral equations. Existence and uniqueness and general properties of solutions of Volterra integral equations, Linear system of VIE's, Resolvent kernel, Fredholm theory of IE's.
Stability theory: Stability of Linear and nonlinear systems of differential equations and Volterra integral equations, Liapunov functions and determinations of stability.
Periodic solutions: Periodic solutions of Linear and nonlinear differential and Intergral equations.

Recommended References

Morris W. Hirsch and Stephen Smale	: Differential Equations, Dynamical systems and Linear Algebra.
R.D Driver	: Introduction to Ordinary Differential Equations.
T.A. Burton	: Stability and Periodic Solutions of Ordinary and Functional Differential Equations.
Rama Mohana Rao	: Ordinary Differential Equations, Theory and Applications.

MAT607: Quantum Mechanics 3.00 Credit Hours

Origin of quantum theory: Black body radiation. Photoelectric effect, Compton effect, Bohr model, De Broglie's hypothesis, Wave properties of matter.
Wave function: wave-particle duality, wave packets, Heisenberg uncertainty principle.
Schrodinger equation: Expectation values, Operators, Ehrenfest's theorem. Time-independent Schrodinger equation & its general solution, Schrodinger equation in momentum space.
One dimensional example: Free particle, potential step, the square well, linear harmonic oscillator, periodic potential.
Formalism of quantum mechanics: Dynamical variables, Unitary transformations, Metric representations of wave functions and operators, The Schrodinger and Heisenberg pictures.
Schrodinger equations in three dimensions: Separation of the equation in different co-ordinates, free particle, square well potential, the hydrogen atom.

Angular momentum: Orbital angular momentum, the eigenvalues and eigenfunctions of L^2 and L_z, Spin angular momentum, Total angular momentum, addition of angular momenta.
Approximation methods: Perturbation theory (non-degenerate and degenerate cases), variational method.
Many-particle systems: System of identical particles, Bosons and Fermions, Two-electron atoms.

Recommended References

B.H. Bransden & C.I. Joachain	: Introduction to Quantum Mechanics.
L.I. Schiff	: Quantum Mechanics.
David J. Griffiths	: Introduction to Quantum Mechanics.

MAT608: Asymptotic and perturbation Methods 3.00 Credit Hours

Asymptotic Expansions: Definitions of asymptotic sequences, expansions, and series. Order symbols and Gauge functions, convergent versus asymptotic series, Uniqueness of asymptotic series, Elementary operations on asymptotic expansions.
Expansion of Integrals: Integration by parts. Laplace's method and Watson's Lemma, method of steepest descents, method of stationary phase. Transform integrals and their asymptotic evaluation.
Differential Equations: Singularities and asymptotic methods of solutions with a large or small parameter (WKB method), Transition points.
Asymptotic matching: Use of asymptotic matching for expansion of integrals. Straightforward expansions of sources of non-uniformity. The method of strained co-ordinates. The method of matched and composite asymptotic expansions.

Recommended References

J.D. Murray	: Asymptotic Analysis.
F. W.J. Olver	: Asymptotic and Special Functions.
A.H. Nafeh	: Perturbation Methods.

MAT609: Similarity Analysis 3.00 Credit Hours

Principle and illustrations of dimensional analysis, systematic calculation of dimensionless products, algebraic theory of dimensional analysis, different procedures, (Rayleigh; Buckingham pie-theorem, stepwise, echelon, proportionalities etc.) for the determination of dimensionless groups and its behaviour for some boundary value problems; Method of similude and introduction to fractional analysis of overall equations, a free parameter method for similarity solution applied to two dimensional boundary layer flows, method of separation of variables, similarity requirements for three dimensional. Axisymmetric velocity and thermal boundary layer laminar flows (both steady and unsteady), group theory method, absorption of parameters and natural co-ordinates in similarity variables, reduction of independent variables, similarity and natural co-ordinates on linearised compressible flow, supersonic and transonic similarity rules. Karman similarity criteria for turbulent shear layers.

Recommended References

A. K. Hazra	: Similarity Analysis

MAT610: Computational Fluid Dynamics and Heat Transfer 3.00 Credit Hours

Introduction to computational Fluid Dynamics (CFD) and Heat Transfer, Basics of the methods used in CFD and Heat Transfer, Conversion equations (mass, momentum, energy and chemical species), Finite and Finite Volume Methods, Grid Generation, space and time discretization schemes, Tri-Diagonal Matrix Algorithm (TDMA), Data Analysis, Data Fusion and Post Processing, The Role of Experimental data in CFD and Heat Transfer.

Recommended References

Abdulnaser Sayma : Computational Fluid dynamics
Dale A Anderson : Computational Fluid Mechanics and heat transfer.
John D. Anderson Jr : Computational Fluid Dynamics

MAT611: Geometry of Differential Manifolds 3.00 Credit Hours

Surfaces and properties of surface: Minimal surfaces, theorem of minimal surfaces, general solution of the natural equations, Riccati equation and its solution, equation of Weingarten. Gauss and Codazzi and their applications. Theoema Egrcegium, Fundamental theorem of surface theory.

Developable and Ruled surfaces: Envelop, characteristic, edge of regression, developable surface, property of lines of curvature on developable, ruled surface, fundamental coefficients and Gaussian curvature for ruled surface, tangent plane to a ruled surface.

Geodesics on a surface: Geodesics, differential equation of geodesics, geodesics on plane, surface, sphere, right circular cone, right helicoid, cylinder, torus etc., geodesic curvature K_g and its formulae. Liouville's formula, geodesic on a surface of revolution. Clairaut's theorem, Bonnet's formula, geodesics on Liouville surface. Gauss-Bonnet theorem, torsion of a geodesic, geodesic parallel.

Mapping of surfaces: Mapping, homeomorphism, isometric lines and correspondence, Minding theorem, conformal, isometric and geodesic mapping. Tissot's theorem.

Differentiable manifolds: Theory of differentiable functions, coordinate functions, charts and atlases, complete, compatibility, differentiable structures, differentiable manifolds, local representation of a function for charts, induced topology on a manifold.

Topology of a manifold: Manifold structure on a topological space, properties of induced topology, topological restrictions on manifolds.

Differentiation on a manifolds: Partial differentiations, equivalence relation and class, smooth map on manifolds, tangent space, tangent bundles, tensor and exterior bundles, tangent map on manifolds.

Vector fields on manifolds: C^{∞}-Vector fields on manifolds, coordinates of vector fields, set of vector fields, theorem on vector fields and its coordinates, Lie brackets of vector fields and properties of φ-related vector fields.

Recommended References

C. E. Weatherburn : Differential Geometry of Three Dimensions.
D. J. Struik : Lectures on Classical Differential Geometry
F. Brickell and R. S. Clark : Differentiable Manifolds: An Introduction.
F. W. Warner : Foundations of Differentiable Manifolds and Lie groups.

MAT612: Theory of Relativity 3.00 Credit Hours

Inertial frame, Galilean transformations, Michelson-Morley experiment, Absolute motion und historical survey. Lorentz transformations, postulates of the special theory of relativity, Lorentz transformation equation, Consequences of Lorentz transformations, relativistic formulae for velocity and acceleration. Minkowski's space and its properties.
Relativistic mechanics: Mass and momentum, Newton's laws of motion, equivalence of mass and energy, transformation formulae for momentum, energy, force and density. Relativistic optics, relativistic electrodynamics and relativistic fluid mechanics. Principle of covariance and principle of equivalence.
Relativistic field equations: Energy-momentum tensor, Principle of Mach and Einstein's law of gravitation, Schwrzschild's solution of Einstein's equation. Newton's law as first approximation.
The three crucial tests of the general theory of relativity.
Cosmology: Cosmology models: (a) Robertson-Walker model (b) Friedmann Model (c) Einstein's model (d) De Sitter model.
Introduction to unified field theory, String cosmology.

Recommended References

I.K. Goyal & K.P. Gupta	: Theory of Relativity.
Steven Weinberg	: Gravitation and Cosmology Principles and Applications of the General Theory of Relativity.
H. Rashid & N. Islam	: Theory of Relativity .

MAT613: Lattice Theory 3.00 Credit Hours

Lattice: Definitions and elementary properties. Modular Lattices and applications to Abstract Algebra. Metric Lattices and distributive Lattices. Reducibility and independence. Complemented Lattices. Boolean algebra, Canonical form of a Boolean Algebra. Boolean Rings, Morphisms, Direct products.
Minimization problem: The Veitch-Darnaugh Map of a Boolean function: Five Variable and Six Variable: maps. Boolean Matrices, Dedekind's characterization of modular lattices. Atomic Lattices and Semimodular Lattices.
Birkhoffs characterization of distributive lattices. Representation of distributive lattices. Stone theorem, Natchbin theorem and Hashimoto's theorem. Distributive lattices with pseudocomplementation. Stone lattice and its characterizations. Stone algebra and its characterization. Distributive, standard and neutral elements. Distributive, standard and neutral ideals. Structure theorems.

Recommended References

G. Birkhoff	: Lattice Theory
G. Gratzer	: General lattice Theory
D.K. Rutherfor	: Introduction to lattice Theory

MAT614: Fuzzy Mathematical Structures 3.00 Credit Hours

Constructing fuzzy sets, Operations on fuzzy sets, t-space and s-norms, α-cuts, Extension principle, Measurement of fuzziness, Fuzzy relations, Fuzzy similarity, Fuzzy ordering, Pattern classification based on fuzzy relations. Fuzzy relational equations. Representation theorems. Interval analysis, Arithmetic operations with applications. Multi-valued logics,

Fuzzy propositions, Fuzzy quantifiers, Linguistic hedges, Approximate reasoning. Fuzzy topologies, F-continuous functions, Fuzzy metric spaces, Fuzzy neighbourhood spaces, Fuzzy convergence, Fuzzy Compact spaces, Fuzzy connectedness, Fuzzy components. Fuzzy substructures of algebraic structures, Fuzzy monoids and automata theory, Fuzzy subgroups and pattern recognition, Free fuzzy monoids and coding theory.

Recommended References

G. J. Klir & U. Clair : Fuzzy Set Theory.
G. J. Khir & Bo Yuan : Fuzzy Sets & Fuzzy Logic Theory and Applications.
R. Lowen : Basic concepts, Techniques and Bibliography.
H.J. Zimmermann : Fuzzy Sets Theory and Its Applications.

MAT615: Advanced Mathematical Methods 3.00 Credit Hours

Gamma and beta functions: Properties of Gamma function, Continuity and convergence of gamma and beta functions, integral form of gamma of n. Asymptotic representation of Gamma function for Large |n|.

Elliptic integral and elliptic Functions: Reduction of elliptic integrals to standard form, properties of elliptic function addition formulae, periods of elliptic function. The probability integral and related functions.

Orthogonal Sets of Functions: Orthogonal & Normalized Function, weight function, orthonormal set of functions, Strum-Liouville problem, Eigenvalues and Eigenfunctions, Gram-Schmidt process, Parseval's equation.

Laguerre's Equations: Solution, Integral and recurrence formula, Differential forms, Othogonality.

Chebyshev Polynomial: Differential equations, Generating functions, Orthogonality, Recurrence relations.

Legendre functions of the second kind $Q_n(x)$: Associated Legendre's functions. Laplace's first & second integral, Recurrence relations, Christoffel's second summation formula, Newmann's integral.

Bessel Functions: Integral representations, Hankel function, Neumann function. Green's function and its applicantions.

Fourier integral theorem and Fourier transforms: Multiple Fourier transforms, Fourier transforms of radially symmetric functions, The solutions of integral equations of convolution type, Use of Fourier transforms in solving Laplace's equation, diffusion equations and wave equations. The double Laplace transform, the interated Laplace transform, the Stieltjes transform and the Hankel transform. The Perseval relation for Hankel transform and the relation between Fourier and Hankel transforms. Use of Hankel transforms in solving partial differential equations.

Boundary value problems: Wave & Heat equation, Fourier-equation of heat conduction, Separation of variables, Laplace's equation, boundary value problems in polar & cylindrical coordinates, telegraph or transmission line equations.

Hypergeometric Equation: Solution of Hypergeometric function and its properties, Confluent Hyprtgeometric functions, Differentiation, Integral forms and linear transformations of hypergeometric functions, Kummer's function, Gauss function.

Hermite Polynimials: Differential equations, Generating functions, Orthogonality, Recurrence relations, Integral representations, Relation with Legendre Polynomial.

Recommended References

R.V. Churchill	: Fourier Series and Boundary Value Problem
B.D. Gupta	: Mathematical Physics.
Harold Jeffreys & Bertha Swirles	: Methods of Mathematical Physics.
Stephenson	: Mathematical Methods.
M.R. Spiegel	: Fourier and Laplace Transform.

MAT616: Mathematical Modeling and Population Dynamics 3.00 Credit Hours

Population dynamics: Simple continuous and discrete models, graphical and stability theory of linear and nonlinear differential equations, nonlinear population models, age-dependent population model, two species linear and nonlinear population models, multi-species models, stochastic models of population, spatial model, optimal control of population model.
Stochastic Model: Stochastic linear and nonlinear models of population, spatial model, optimal control of population model.
Microbial population models: Microbial population, Chemostat, growth of microbial populations, stability of the models.
Virus dynamics: Virus, immunity, cells, epidemic models, dynamics of infectious diseases, AIDS/HIV models, dynamics of hepatitis B virus, age-dependent epidemic model, stochastic epidemic model.
Anti-virus drug therapy: Control of an epidemic model, drug therapy, vaccination effects, treatment of HIV, CTL response, and immune responses eliminate infected cell, simplest models of immune response dynamics.
Dynamics with diffusion: Diffusion equation, single and multi-species diffusion models, competition model with diffusion, epidemic model with diffusion, diffusion in artificial kidney.
Applications: Blood pressure and its measurements, glucose concentration in blood, heart function test, and optimization models for blood testing.

Recommended References

J.D. Murry	: Mathematical Biology.
J.N. Kapur	: Mathematical Models in Biology and Medicine.
Edward Beltrami	: Mathematics for Dynamic Modeling.
Leah Edelstein-Keshet	: Mathematical Models in Biology.
M.A. Nowak & R.M. May	: Virus Dynamics, Mathematical Principles of Immunology and Virology.

MAT617: Rings and Modules 3.00 Credit Hours

Rings of fractions and embedding theorems. Local rings and Noetherian rings. Rings with ore conditions and related theorems.
Field extensions and finite fields. Wedderburn's theorem on finite dimension rings. Jacobson's work on commutativity condition on division rings. Modules, submodules and direct sums. R-homomorphisms and quotient modules. Completely reducible and free modules. Sequence and exact sequences of modules. Projective and injective modules. Semisimple and simple rings. Artinian and Noetherian modules. Categories and functors, exactness of functors between module categories. Semisimple modules and rings. Radical and socle. The tensor product, flat modules and regular rings. Application of rings and modules to abelian groups, to vector spaces with a linear transformation, to languages, grammars, machines, coding theory etc.

Recommended References

Kenneth S. Miller	: Elements of Modern Abstract Algebra
Hiram Palety and Paul M. Weichsel	: A First Course in Abstract Algebra
O. Zariski and P. Samuel	: Commutative Algebra

MAT618: Graph Theory 3.00 Credit Hours

Introduction: Definition of Graph, Definition types of graphs Application of graphs, Brief history of graph theory.

Paths and circuits: Sub graphs, Walks, Paths, Circuits, Euler graphs, Components, Connected and disconnected graphs, Isomorphism, Puzzle with Multicolored cubes, Hamiltonian paths and circuits, The travelling salesman problem.

Trees and Fundamental circuits: Definition of trees, Properties of trees, Distance and centers in a trees, Rooted and Binary trees, Spanning trees, Fundamental circuits and cut vertices, Cut sets properties of cut sets, Fundamental circuits and cut sets, Connectivity and separability 1-Isomorphism, 2-Isomorphism.

Vector spaces of a Graph: Sets with one and two operations, Modular Arithmetic and Galois fields, Vectors and vector spaces, Vector space associated with a graph, Basis vectors of a graph, Circuit and cut-set subspaces, Orthogonal vectors and spaces, Intersection and join of W_n and W_s.

Matrix Representation of Graphs: Incidence matrix, Sub matrices of A(G), Circuit matrix, Rank and fundamental circuit matrix, Cut set matrix, Relationships among A_f, B_f and C_f path matrix, Adjacent matrix.

Directed graphs: Definition of directed graph, Types of directed graph, Digraph and Binary relations, Directed paths and connectedness, Euler digraphs, Fundamental circuits and digraphs Matrices A, B and C of digraphs, Acyclic digraphs and Decylization.

Graphs in switching and coding theory: Contact networks, Analysis of contact networks, Synthesis of contact networks. Sequential switching networks, Unit cube and its graph, Graphs in coding theory.

Electrical networks analysis by graph theory: Definition of electrical network, Kirehhoffies current and voltage laws, Loop currents and node voltages, R.LC networks with independent sources, Nodal analysis, RLC networks with independent sources loop analysis. General lumped, linear, Fixed networks.

Recommended References

C. Berge	: The theory of Graphs.
F. Harary	: Graph Theory.
K. R. Parthasarathy	: Basic Graph Theory.
Narsingh Deo	: Graph Theory.
Doughlas B West	: Graph Theory.

MAT619: Advanced Number Theory 3.00 Credit Hours

Quadratic residuacity: Quadratic residues and nonresidues, Euler criterion, Legendre symbol. Gauss's lemma, law of quadratic reciprocity, Jacobi's symbol.

Average orders of arithmetic functions: Lim sup, Lim inf, average orders of the arithmetical functions.

Distribution of prime numbers: Bertrand's postulate, Chebyshcvs theorem, the function *Q(x)* and *y/(x)*. The prime number theory; elementary proof via Selberg's lemma, complex analytical proof.

Primes in arithmetic progressions: Characters of an Abelian group, L-functions, Dirichlet's proof of infinitude of primes in arithmetic progressions.

Algebraic number theory: Noetherian rings and Dedekind domains, ideal classes and the unit theorem, units in real quadratic field.

Recommended References

G.H. Hardy and M. Whyle : An introduction to the theory of numbers.
S. Rose : A course in number theory.
P. Samuel : Theory of algebraic numbers.

MAT620: Real Function Theory 3.00 Credit Hours

Algebra, Sigma Algebra, Cantor and Borel sets, Concept of measure, Properties of measure, outter measure, Lebesgue measure, Lebesgue's Monotone convergence theorem, Fatou's Lemma, Lebesgue's dominated convergence theorem, measurable set and functions, Integration of simple and complex functions, Reisz Representation theorem, Basic topological properties of Euclidean spaces, Covering theorems, Regularity properties of functions.

Classical Banach spaces: L^p spaces, Convex functions and inequalities, Conjugate exponents, Minkowski and Holder inequalities, completeness of L^p spaces, approximation and density in L^p, Bounded linear functions on L^p spaces.

Hilbert space: Inner product and linear functional, the triangle inequality, parallelogram low, Bessel's inequality, approximation problems. Abstract measure and integration, measure spaces and measurable functions, integration, signed measures, the Radon-Nikodym theorem.

Recommended References

Paul Halmos : Measure theory
W. Rudin : Real and Complex Analysis
B. K. Lahiri : Functional Analysis
Royden : Mathematical Analysis
Apostal : Mathematical Analysis

MAT621: General Algebraic Topology 3.00 Credit Hours

Basic topological concepts: bases and subbases, subspaccs, continuous maps, weak and strong topologies, quotient spaces. Product spaces.

Convergence: nets and filters. Separation axioms, regular spaces, completely regular spaces, Normal spaces, Urysohm's lemma, Characterization of Normality. Countability properties. Compact and Locally compact spaces, compactification, Metrization, Baire theorem.

Connected spaces: Pathwise and local connectedness. Uniform spaces, uniformizability and uniform metrizability.

Function spaces: Pointwise and uniform convergence, compact open topology. Commutative Topological Groups, Elementary considerations, Bases. Subgroups and Quotient groups, completion of topological groups. Continuous homomorphisms, Groups of functions. Uniformities and metrization.

Recommended References

George F. Simmons : Introduction to Topology and Modern Analysis.
J. L. Kelley : General Topology.

J. P. May : A Concise Course in Algebraic Topology
Allen Hacher : Algebraic Topology

MAT622: Functional Analysis 3.00 Credit Hours

Topological Linear Spaces: Convex lets and hyper planes, semi norms, locally convex spaces, weak topology, compact convex sets, duality in Banach space.
Linear Operators: Continuity and boundedness, fundamental properties of bounded operators uniform boundedness principle, conjugate of bounded linear operators, adjoint operator and its duality, bounded linear operators in Hilbert spaces, unbounded linear operator.
Spectral Analysis of Linear Operators: Spectrum and the resolvent operator, spectrum of a bounded linear operator, compact operators.

Spectral Analysis in Hilbert spaces: Bilinear and quadratic forms, symmetric operators. Normal and self-adjoint operators, the spectral theorem for bounded self-adjoint operators, unbounded self-adjoint operators.

Nonlinear Compact Operators and Monotonicity: Banach Fixed point theorem with applications, Schauder fixed point theorem, Frechet derivative. Newton's method for nonlinear operators, positive and monotone operators.

Recommended References

A.E. Taylor : Introduction to Functional analysis
V. Hutson and J.S. Pym : Applications of Functional analysis and Operator Theory.
Walter Rudin : Functional Analysis.
N. Dunford and J. Schwartz : Linear operators General Theory.

MAT623: Partial Differential Equations (PDEs) 3.00 Credit Hours

Classification of PDE (parabolic, elliptic, hyperbolic), Existence, uniqueness and represention of solutions for the PDE (wave equation & heat equation). Cauchy, Dirichlet and Neumann boundary-value problems for the Laplace and Poisson equation. Potential theory in two and higher dimensional domains, initial and boundary value problems of heat equation and wave equation, Maximum principle of parabolic equation; Sturm-Liouville systems, boundary and eigenvalue problems, method of eigenfunction expansions.

Recommended References

F. Ayres : Differential Equations.
R. Dennemeyer : Introduction to Partial Differential Equations.
M. L. Khanna : Partial Differential Equations.
B. D. Sharma : Partial Differential Equations.
Tyn Myint- U : Partial Differential Equations for scientists and engineers

MAT624: Biomathematics 3.00 Credit Hours

Blood flows: Concepts of fluid dynamics, Concepts about blood, Cardiovascular system, and Blood flows, Viscosity and Reynolds number of blood flows, Rheological behavior of blood, Steady non-Newtonian fluid flows in circular tube, Newtonian pulsatile flows in rigid and elastic tubes, Blood flow through artery with mild stenosis.

Magnetohydrodynamic: Concepts of Magnetohydrodynamics one dimensional Magnetohydrodynamics equation, The momentum equation, The equation of motion of moving media, The equation of motion of a conducting media, Interaction between flow field and Magnetic field. The magnetic Reynolds number, Alfven's theorem, Alfen's waves, Application of the equation of motion to blood flow. Hartmann flow, Couette and Poiseuille flows, Application to blood flow.

Epidemic models: Differential equations in the theory of epidemics, Deterministic models with and without removal, Control of an epidemic, stochastic models and the dynamics of inflections diseases.

Diffusion and diffusion-reaction models: Diffusion equation in artificial kidney, Oxygen diffusion through living tissues, Diffusion through membrane, epidemic model with diffusions.

Applications: Blood pressure and its measurements, models for gas exchange and air flow in lungs. Glucose concentration in blood, Arterial pulse, Human Erythrocytes from plasma, A heart function test, Physical interpretation of heal function, Nervous excitation, Birth and death processes, Optimization models for blood testing.

Recommended References

Y. C. Fung	: Biomechanics
J. N. Kapur	: Mathematical Models in Biology and Medicine.
J. D. Murray	: Mathematical Biology.
J. G. Defares	: The Mathematics of Medicine and Biology.
R. N. Roy	: A text book of Biophysics.
V. C. Ferraro and C. Plumpton	: An Introduction to Magneto Fluid Mechanics.

MAT625: Industrial Mathematics 3.00 Credit Hours

Statistical reasoning: Random variables, Uniform distributions, Gaussian distributions, the binomial distribution, The Poisson distribution.

Data acquisition and manipulation: The z-transformation, linear recursions, Filters, Stability, Polar and Bode plots, Aliasing, Closing the loop.

The discrete fourier transform: Real time processing, Properties of DFT, Filter design, the fast Fourier transform, Image processing.

Frequency domain method: The frequency domain, Generalized signals, Plants in cascade Surge impedance, Stability, Dilters, Feedback and root-locus, Nyquist analysis, Control.

Microeconomics: Supply and demands, Revenue, Cost and profit, Elasticity of Demand, Duopolistic competition, Theory of production.

Ordinary differential equations: Separation of variables, Mechanics, Linear and non-linear ODEs System.

Partial differential equations: Lumped versus distributed, The big six PDEs, Separation of variables, Unbounded spatial domains, Periodic steady state, Other distributed model.

Monte Carlo methods: Computing integrals, Mean time between failure, Servicing requests, The newsboy problem.

Galerkin's method: Galerkin's requirement, Eigenvalue problems, Steady problems, Transient problems, Finite elements.

Recommended References

Charles R. MacCluer	**:** Industrial Mathematics
Avner Friedman and Walter Littman	**:** Industrial Mathematics

MAT626: Computational Stellar Astrophysics 3.00 Credit Hours

The Solar System: Two-body orbital motion, application to detection of other planetary system, restricted three-body problem. Theories for the origin of the solar system. The 3-body problem, Lagrangian equilibrium points, effects of drag forces, theories of tides, the distributing functions & Perturbations.

Stellar structure & Evolution: Observational Properties of stars, H-R diagram, main sequence, giants and white dwarfs. Properties of stellar interiors, radiative transfer, equation of Stellar, Nuclear reactions, Convection. Models of the sun.

The Stellar Galaxy: The interstellar medium & galactic structure and dynamics. Physical and Chemical Characteristics of gas and dust components, influence on star formation. Excitation of ISM, Collapse of ISM to stars.

Recommended References

Baidyanath Basu	: An Introduction to Astrophysics
Bohm-Vitense	: Stellar-Astrophysics
M Schwarzschild	: Stellar Structure and Evolution

MAT627: Dynamical Systems 3.00 Credit Hours

Basic concepts: Basic definitions & examples. Phase space, phase portrait, discrete dynamics, continuous dynamics, topological dynamics, ergodic theory, topological conjugacy, fixed and periodic points, graphical analysis, iteration, hyperbolic points, hyperbolic dynamics.
Chaotic dynamical systems: Definitions of chaos, sensitive dependence on initial conditions, period three theorem, orbit structure, Cantor set, basin of attractor & repellor, strange attractor and Lyapunov exponents.
Discrete dynamical systems: One parameter family of maps, contractions & fixed point theorem, stability of fixed points, family of logistic map, tent map, doubling map, linear maps, iterative map, quadratic family of maps, small horseshoe map, expanding map.
Differential dynamical systems: One & two dimensional linear & nonlinear differential equations, sinks, source & saddles, stability, population models, Lotka-Volterra models, Henon map, Lorenz map, hyperbolic fixed point, manifold and sub-manifold, stable and unstable manifold, stable manifold theorem, Hartman-Grohman theorem, Hadamard-Perron theorem, Smale theorem.
Bifurcations: Bifurcations, bifurcations points, bifurcations of quadratic maps, saddle-node, period doubling, pitchfork, transcritical bifurcation, bifurcation diagram.
Symbolic dynamical systems: Sequence spaces, shit map, properties of shift maps, symbolic dynamics, itinerary, sub shift of finite type.
Fractals: The chaos game. Cantor set revisited. Sierpinski triangle, Koch snowflake, topological dimension, fractal dimension.

Recommended References

A. Katok and B. Hasselblatt	: Introduction to modern theory of dynamical systems.
R.L. Devaney	: A First course in chaotic dynamical systems
R.A. Holmgren	: A first course in discrete dynamical systems

MAT628: Operations Management 3.00 Credit Hours

Introduction: Introduction to Operations Management, The scope of OM, OM and decision making, Productivity, Product mix, Strategy, Competitiveness.
Capacity Planning: Strategic capacity decision, Strategy formulation, Definition and measuring capacity, evaluating capacity alternatives.
Quality Control: Management of quality, Statistical process control, Variations and control, Control Charts. Process capability, Improving process capability, Capability analysis.
Forecasting: Features common to all forecasts, Elements of good forecast, Steps in the forecasting process, Accuracy and control of forecasting, Applications of Forecasting models.
Inventory Control: Nature and important of inventories. Introduction to basic inventory models, Economic order quantity (EOQ) model, EPQ model. Fixed order interval model, Single period model.
Scheduling: Scheduling in high-volume system, intermediate-volume system, low-volume system, Scheduling methods of Linear Programming Scheduling jobs through two work centers, Minimizing scheduling difficulties, scheduling the work force.
Simulation: Basic terminology of simulation, steps in simulation process, Application of simulation, Simulation with random variables, Advantage and limitations of using simulations
Project Management: Behavioral aspect of project management, Key decisions in project management, Pert(program evaluation and review technique), CPM(critical path method), Deterministic time estimates, Probabilistic time estimate, Applications.

Recommended References

William. J. Stevenson	: Operations Management
Wayne L. Winston	: Operations Research
Hiller and Lieberman	: Introduction OR

MAT629: Riemannian Geometry 3.00 Credit Hours

Introduction: Fundamental notions, Non-Euclidean geometry, symmetric spaces, Riemannian manifolds, Riemannian submanifolds, Pseudo-Riemannian manifolds.
Curvature of Riemannian manifolds: Einstein space, Constant Riemannian curvature. Riemannian curvature, Recurrent space, Ricci-recurrent space, Geodesic curvature, scalar curvature, sectional curvature, Ricci curvature, Ricci decomposition, Weyl curvature, conformal curvature tensor and Einstein manifolds.
Smooth Manifolds: Functions on smooth manifolds. Pull-back of function, Tangent vector and tangent space, push-forward of tangent vectors, smooth vector fields, Lie brackets (communtator). Lie algebra, Examples of matrix groups.
Bundles: Vector bundles, Fibre bundles. Principals bundles. Tangent bundles. Cotangent bundles, Line bundle, Jet bundles, Tensor bundles, dual and normal bundles, subbundles. Vector bundle morphisms and isomorphisms.
Metrics and Connections: Metrics and connections on bundles, Riemannian metrics, Affine connection, torsion and curvature tensors. Parallel transport. Geodesies, Levi-Civita connection, Coordinate representation of the curvature tensor.
Exterior Differential Calculus: Differential form, Exterior derivatives, exterior algebra (Grassman algebra), Grassman manifolds, projective space, the exterior derivative in calculus, wedge product, Poincare' s Lemma.

Symplectic Geometry: Symplectic topology, Symplectic Space, symplectic manifolds, Symplectic structure, Symplectomorphism, Darboux theorem on symplectic manifold and related theorems on symplectic manifolds.

Contact Ceometry: Contact structure, Contact space manifolds, Durboux theorem on contact manifold, complex manifolds, complex projective space, theorem on complex contact manifolds.

Recommended References

C. S. Isham : Modern Differential Geometry

V. I. Arnold : Mathematical Methods of Classical Mechanics

R. W. R. Darling : Differential Forms and Connections

R.O. Wells Jr. : Differential Analysis on Complex Manifolds