# UNIVERSITY OF DHAKA

# Syllabus of the Department of Mathematics

*for*

## M.S, M.phil./Ph.D. Coursees

*for the*

**Sessions :** 2009-2010 to 2011-2012

2012-2013 to 2014-2015


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**Department of Mathematics**
**M. S. in Pure Mathematics**
**M. S. in Applied Mathematics**
**Sessions: 2009- 10 to 2011-2012**

## Pure Mathematics

**Group A (Non-Thesis Group)**

Credit Requirement **32 Credits**

| | |
|---|---|
| Course 7 | 28 Credits |
| Viva Voce | 4 Credits |

**Group B (Thesis Group)**

Credit Requirement **34 Credits**

| | |
|---|---|
| Course 6 | 24 Credits |
| Thesis | 8 (6+2) Credits |
| Viva Voce | 2 Credits |

## Applied Mathematics

**Group A (Non-Thesis Group)**

Credit Requirement **32 Credits**

| | |
|---|---|
| Course 7 | 28 Credits |
| Viva Voce | 4 Credits |

**Group B (Thesis Group)**

Credit Requirement **34 Credits**

| | |
|---|---|
| Course 6 | 24 Credits |
| Thesis | 8 (6+2) Credits |
| Viva Voce | 2 Credits |

The M.S. programme has duration of one academic year. The department offers programs in Pure Mathematics and in Applied Mathematics. In either program there is provision for taking up thesis work, subject to the approval of the academic committee of the department.

Each student in Group A (non-thesis group) of either program has to take seven courses (each of 4 credits), while each student in Group B (thesis group) has to take six courses, out of the courses enumerated below, subject to conditions, laid down by the academic committee.

**Evaluation:** Incourse 30 marks (Attendance 5 + Incourse examination 25), Final Examination (Theory, 4 hours): 70 marks. **Eight** questions will be set, of which any **Five** are to be answered.

## COURSE TITLES

### PURE MATHEMATICS

MTP 501 : THEORY OF GROUPS 4 Credits

MTP 502: THEORY OF RINGS AND MODULES 4 Credits

MTP 503: ADVANCED NUMBER THEORY 4 Credits

MTP 504: REAL FUNCTION THEORY 4 Credits

MTP 505: COMPLEX FUNCTION THEORY 4 Credits

MTP 506: GENERAL TOPOLOGY 4 Credits

MTP 507: FUNCTIONAL ANALYSIS 4 Credits

MTP 508: LIE GROUPS AND LIE ALGEBRAS 4 Credits

MTP 509: FUZZY MATHEMATICAL STRUCTURES 4 Credits

MTP 510: SPECIAL TOPICS 4 Credits

### APPLIED MATHEMATICS

MTA 511: ANALYTICAL DYNAMICS 4 Credits

MTA 512: QUANTUM MECHANICS 4 Credits

MTA 513: THEORY OF RELATIVITY 4 Credits

MTA 514: FLUID DYNAMICS 4 Credits

MTA 515: MAGNETOHYDRODYNAMICS 4 Credits

MTA 516: MATHEMATICAL HYDROLOGY 4 Credits

MTA 517: THERMODYNAMICS AND

STATISTICAL MECHANICS 4 Credits

MTA 518: ELECTRODYNAMICS 4 Credits

MTA 519: AERODYNAMICS 4 Credits

MTA 520: DYNAMICAL METEOROLOGY 4 Credits

## COURSES COMMON TO PURE & APPLIED MATHEMATICS

MTA/MTP 521: DIFFERENTIAL AND INTEGRAL EQUATIONS 4 Credits

MTA/MTP 522: OPERATIONS RESEARCH 4 Credits

MTA/MTP 523: NUMERICAL METHODS FOR DIFFERETIAL EQUATIONS 4 Credits

MTA/MTP 524: GEOMETRY OF DIFFERENTIAL MANIFOLDS 4 Credits

MTA/MTP 525: ASYMPTOTIC AND PERTURBATION THEORY 4 Credits

MTA/MTP 526: DYNAMICAL SYSTEMS 4 Credits

MTA/MTP 527: MATHEMATICAL BIOLOGY 4 Credits

MTA/MTP 528: RIEMANNIAN GEOMETRY 4 Credits

MTA/MTP 529: OPERATIONS MANAGEMENT 4 Credits

MTA/MTP 530: SPECIAL TOPICS 4 Credits

# DETAILED SYLLABUS
# PURE MATHEMATICS

## MTP 501: THEORY OF GROUPS 4 Credits

1. Centralizer and normalizer in a group, p-groups; characteristic subgroups, classification of groups of small orders.

2. Permutation groups; cycles and orbits; transitivity; representation of a group by permutations: the alternating group An

3. Sylow theorems; falsity of the converse of Lagrange theorem, finite p-groups; groups of orders p, $p^2$,pq,$p^3$.

4. Automorphisms: automorphisms of algebraic systems; automorphisrns of groups; inner automorphisms.

5. Group Extensions: direct product of groups; cyclic extensions; split extensions; semi-direct product; Wreath product.

6. Solvable, supersolvable and nilpotent groups: commutator and commutator group; composition series; subgroups and factor groups or solvable groups; normal series; upper and lower central series; subgroups and factor groups of nilpotent groups.

7. Group Representations: permutational representations; Matrix representation; G-modules: complete reducibility; Schur's lemma; Maschke's theorem.

8. Group Characters: irreducible, reducible, faithful characters; orthogonality relations; linear characters; character relation of the first kind; group algebra; character algebra; character relations of the second kind.

***Reference Books:***


1. Marshall Hall. .Jr. The Theory of Groups.
2. W. Ledermann. Introduction to Group Theory.

3. Martin Burrow. Representation Theory of Finite Groups.
4. W. Ledermann. Introduction to Group Characters.

## MTP 502: THEORY OF RINGS AND MODULES

**4 Credits**

1. Rings of fractions and embedding theorems. Local rings and Noetherian rings.

2. Rings with Ore conditions and related theorems.

3. Field extensions and finite fields. Wedderburn's theorem on finite dimension rings.

4. Jacobson's work on commutativity of rings.

5. Modules, submodules and direct sums, R-homomorphisms and quotient modules.

6. Completely reducible and free modules.

7. Sequences and exact sequences of modules. Projective and injective modules.

8. Semisimple and simple rings.

9. Noetherian and Artinian modules. Wedderburn-Artin theorem.

***Reference Books:***

1. Kenneth S. Miller. Elements of Modern Abstract Algebra.
2. Hiram Paley and Paul M. Weichsel. A First Course in Abstract Algebra .
3. Zariski, O. and Samuel, P. Commutative Algebra.

## MTP 503: ADVANCED NUMBER THEORY

**4 Credits**

1. Quadratic residuacity: Quadratic residues and nonresidues, Euler criterion, Legendre symbol. Gauss's

lemma, law of quadratic reciprocity, Jacobi's symbol.

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

3. Distribution of prime numbers: Bertrand's postulate, Chebyshevs theorem, the function $\theta(x)$ and $\psi(x)$. The prime number theory; elementary proof via Selberg's lemma, complex analytical proof.

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

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

*Reference Books:*

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

**MTP 504: REAL FUNCTION THEORY**

**4 Credits**

1. Basic topological properties of Euclidean spaces. Algebra of sets, Cantor and Borel sets.

2. Lebesgue measure: Outer measure, measurable sets and Lebesgue measure, non-measurable set, measurable functions, Littlewood's three principles, Egoroff's theorem.

3. Lebesgue integral: Lebesgue integral of a bounded function, integral of a non-negative function, the general Lebesgue integral, convergence in measure.

4. Differentiation and integration: Differentiation of

monotone functions, function of bounded variation, differentiation of an integral, absolute continuity.

5. The classical Banach spaces: $L_p$-spaces, Holder inequality and Minkowski inequality, convergence and completeness.

6. General measure and integration theory: Introduction to abstract measure, signed measure, Hohn decomposition theorem, product measure, Fubini's theorem.

*Reference Books:*

1. H. L. Royden. Real Analysis
2. P.R. Halmos. Measure Theory.

## MTP 505: COMPLEX FUNCTION THEORY

**4 Credits**

**1. Convergence:** Uniform convergence of power series. Weierstras's theorem, Absolute and uniform convergence of infinite products.

**2. Analytic functions:** Open mapping theorem, Maximum modulus principle, Convex functions. Hadamard three-circles theorem. Caratheodory's inequality. Theorems of Poisson, Jensen, Borel and Caratheodory. Space of analytic functions.

**3. Harmonic functions**: Basic properties, Mean value theorem. Maximum modulus principle. Poisson's Kernel, Harmonic functions of a disc. Dirichlet problem on a disc.

**4. Power Series:** Basic Properties, Relations among power series, Fourier series and Dirichlelt series. Sufficient conditions of regular and singular points. Theorems of Hurwitz, Vitali and Montel.

**5. Entire functions:** Basic properties, Order, type. Growth properties of entire functions with their Zeros. Jensen's Inequality for entire function. Expression of order and type in terms of Taylor coefficients. Hadamard product of entire functions, order and type.

6. **The space $C^n$:** Introduction to the theory of analytic function of several complex variables. Formal power series about Z. in $C^n$, Poly-cylinder. Distinguished boundary. Reinhardt domain. analytic function. Complex holomorphic functions. Taylor series expansion. Cauchy's integral.

***Reference Books:***


1. A.I. Markushevich. Theory of functions of a complex variable. Volume I. & Vol. II. Prentice-Hall, INC. N.J.,1965.
2. Ralph Philip Boas. Entire Functions (1954), Academic Press Inc. New York. N.Y.
3. Salomon Bochner and William Ted Martin. Several Complex variables (1948).
4. L.I. Ronkin. Theory of entire functions of several complex variables, 1974.


**MTP 506: GENERAL TOPOLOGY 4 Credits**

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

2. Product spaces.

3. Convergence: nets and filters.

4. Separation axioms, regular spaces, completely regular spaces, Normal spaces, Urysohm's lemma, Characterization of Normality.

5. Countability properties.

6. Compact and locally compact spaces, compactification.

7. Metrization; Baire theorem.

8. Connected spaces: Pathwise and local connectedness.

9. Uniform spaces, uniformizability and uniform metrizability.

10. Function spaces: Pointwise and uniform convergence, compact open topology.

11. Commutative Topological Groups, Elementary considerations, Bases. Subgroups and Quotient groups, completion of topological groups. continuous homomorphisms, Groups of functions. uniformities and metrization.

***Reference Books:***

1. George F. Simmons. Introduction to Topology and Modern Analysis.
2. James Dugundi. Topology.
3. J. L Kelley. General Topology.

**MTP 507: FUNCTIONAL ANALYSIS 4 Credits**

1. **Topological Linear Spaces:** Convex sets and hyperplanes, seminorms, locally convex spaces, weak topology, compact convex sets, duality in Banach spaces.

2. **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.

3. **Spectral Analysis of Linear Operators:** Spectrum and the resolvent operator, spectrum of a bounded linear operator, compact operators.

4. **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.

5. **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.

***Reference Books:***


1. A.E. Taylor- Introduction to Functional analysis, John Wiley & Sons, Inc.1967
2. V. Hutson and J.S. Pym- Applications of Functional Analysis and Operator them). Academic press, 1980.
3. W. Rudin- Functional Analysis. McGraw-Hill, Inc. International. 1991.
3. N. Dunford and J Schwartz. Linear operators, General Theory. Wiley, 1958.


## MTP 508: LIE GROUPS AND LIE ALGEBRAS

**4 credits**

1. **Manifolds:** Some basic notation and terminology. Manifolds and differentiable manifold, Some important results on manifolds.

2. **Closed Linear Groups:** Topological groups, Lie Algebras of the closed linear groups.

3. **Lie Groups and Lie Algebras:** Lie groups, A matrix representation of the topological group R. Linear Lie groups, Lie subgroups.

4. **The Exponential of a matrix:** Convergent power series, matrix power series.

5. **Lie Algebras:** The exponential map of a Lie group. General lie algebras.

6. **Analyticity of Lie groups:** The Lie algebra defined

# DETAILED SYLLABUS
# APPLIED MATHEMATICS

## MTA 511 : ANALYTICAL DYANMICAS 4 credits

1. Motion relative to the rotating earth.

2. Motion of a rigid body about a fixed point. Space cone, body cone, invariable cones, poinsot's construction of rigid body motion.

3. Inertia tensor and related properties.

4. Holonomic and nonholonomic dynamical systems and derivation of Lagrange's equations in generalized co-ordinates, Applications of Lagrange's equations for impulsive motion and motion of spinning top.

5. Ignoration of coordinates and Routhian functions.

6. Problems of small oscillations and determination of normal modes of oscillations.

7. Hamilaton's variational principle of mechanics, Hanmilton's principle of least action. Fermat's principle of least action.

8. Brachistochorne problems.

9. Poisson's and Lagrange's brackets and applications to Hamilton's mechanics.

10. Canonical transformations, Generating function, Invariance of Canonical transformation, Invariance of Lagrange & Poisson brackets under canonical transformations.

***Reference Books:***


1. Goldstein. Classical Mechanics.
2. Gupta, Kumar, Sharma. Classical Mechanics.
3. Spiegel M. Theoretical Mechanics.

## MTA 512: QUANTUM MECHANICS **4 credits**

1. **Origin of Quantum theory:** Black body radiation. Photoelectric effect, Compton effect, Bohr model, De Broglie's hypothesis, Wave properties of matter.

2. **Wave function:** wave-particle duality, wave packets, Heisenberg uncertainty principle.

3. **Schrödinger equation:** Expectation values, Operators, Ehrenfest's theorem. Time-independent Schrödinger equation & its general solution, Schrödinger equation in momentum space.

4. **One dimensional examples:** free particle, potential step, the square well, linear harmonic oscillator, periodic potential.

5. **Formalism of quantum mechanics:** Dynamical variables, Unitary transformations, Metric representations of wave functions and operators, The Schrödinger and Heisenberg pictures.

6. **Schrödinger equations in three dimensions:** Separation of the equation in different co-ordinates, free particle, square well potential, the hydrogen atom.

7. **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.

8. **Approximation methods:** Perturbation theory ( non-degenerate and degenerate cases). variational method.

9. **Many-particle systems:** System of identical particles, Bosons and Fermions, Two-electron atoms.

***Reference Books:***

4. B.H. Bransden & C.I. Joachain, Introduction to Quantum Mechanics.

5. L. I. Schiff, Quantum Mechanics.
6. David J. Griffiths, Introduction to Quantum Mechanics.

## MTA 513 : THEORY OF RELATIVITY 4 credits

1. Inertial frame, Galilean transformations, Michelson-Morley experiment, Absolute motion und historical survey.

2. Lorentz transformations. postulates of the special theory of relativity, Lorentz transformation equation, Consequences of Lorentz transformations, relativistic formulae for velocity and acceleration.

3. Minkowski's space and its properties.

4. Relativistic mechanics: Mass and momentum, Newton's laws of motion, equivalence of mass and energy, transformation formulae for momentum, energy, force and density.

5. Relativistic optics, relativistic electrodynamics and relativistic fluid mechanics.

6. Principle of covariance and principle of equivalence.

7. 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.

8. The three crucial tests of the general theory of relativity.

9. Cosmology: Cosmology models: (a) Robertson-Walker model (b) Friedmann Model (e) Einstein's model (d) De Sitter model.

10. Introduction to unified field theory, String cosmology.

*Reference Books:*

1. Goyal I.K., Gupta K.P. Theory of Relativity.
2. Steven Weinberg, Gravitation and Cosmology Principles and Applications of the General Theory of Relativity.
3. Rashid H., Islam N. Theory of Relativity (in Bengali).

## MTA 514: FLUID DYNAMICS **4 credits**

**1. Fundamental concepts:** Newton's law of viscosity. Newtonian and non-Newtonian fluids. Body and surface forces, Stress and Rate of strain and their relation.

2. Derivation of the Navier-Stokes equations of motion and its general properties.

**3. Some exact solutions of the Navier-Stokes equations:**

i) **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.

ii) **Unsteady plane flows:** Flow between two parallel plates, Flow over a suddenly accelerate flat plate, Flow over an oscillating plate.

**4. Small Reynolds number flows:** Differential equation of very low motion, Slow motion over a sphere, Hydrodynamic theory of lubrication.

**5. 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

3. Precipitation.
4. Evaporation and transpiration.
5. Infiltration and soil moisture, green Ampt method.
6. Ground water in Hydrologic cycle.
7. Rainfall runoff relations: Sources of stream flow, excess rainfall and Direct runoff. Abstraction using infiltration Equation, SCS method for abstraction, index method. Travel time. streamflow, Hydrographs.
8. Unit Hydrograph methods and its applications and synthetic unit Hydrograph.
9. Instantaneous Unit Hydrograph (IUH) and its application.
10. Flood routing: Basic equations, Rescrvior flood routing, River flood routing, Lumped flow routing. Distributed flow routing.
11. Frequency Analysis: Rational method. Empirical formulae, Return Period, Extreme value distributions, Frequency anlysis using frequency factors.
12. Linear Channels.
13. Conceptual and Mathematical Models: (i) Nash model (ii ) Time area Method Clerk's model (iii) Dooge's model (iv) Chow and Kulandaiswany Model (V) Muskingum Model.
14. Hydrodynamic Models: (i) Saint-Venant Equations from Navier -Stokes Equations. (ii) Kinematic Wave *(KW)* Models. (iii) Diffusion Wave Models. (iv) Steady dynamic Wave Models. (v) Dynamic Wave Models. (vi) Gravity Wave Models.
15. Flood forecasting.

*Reference Books:*

1. Applied Hydrodogy by Ven-Te-Chaw et.al.
2. A text book of Hydrology by P . Jayarami Reddy.
3. Hydrologic System Vol I & II by V.P. Singh.
4. Engineering Hydrology by V. Subrumanga.
5. Hydrology by H.M. Raghunath.

## MTA 517: THERMODYNAMICS AND STATISTICAL MECHANICS. 4 credits

1. Equations of state.

2. Work, Coefficients of expansion and compressibility.

3. The first law of thermodynamics and the applications. Changes of phase.

4. The Second law of Thermodynamics, Efficiencies of reversible engines. The Clausias Claperyon equations, Stefan's Law. Entropy, Combined applications of the first and the second law.

5. Kinetic Theory of an ideal gas.

6. The distributions of molecular Velocities.

7. Mean free path. Coefficient of Viscosity, Thermal conductivity. Coefficient of diffusion.

8. The Maxwell-Boltzamann Statistics, Quantum Theory of specific heats.

9. Elements of Fermi-Dirac statistics and Bose-Einstein statistics.

## MTA 518: ELECTRODYNAMICS 4 credits

**1. Maxwell's equations:** Equation of continuing, displacement current, The Maxwell's equations. their differential forms. Maxwell's equation in free space. Energy in electromagnetic Fields. Poyanting theorem.

**2. Propagation of plane electromagnetic works:** Electromagnetic works in free space; Energy flow due to plane electromagnetic waves; plane electromagnetic works in mater in isotropic dielectric, in anisotropic, dielectric and in conducting media; polarization of electromagnetic waves. **Interaction of electromagnetic waves with matter**: Boundary conditions for the electromagnetic field vectors B.E.D, and H3eat the interface between two media; Reflection and refraction of the boundary of two non conducting media; General treatment of reflection and refraction- Fresnels equations; Basic concepts about scattering; Scattering by free electronics (Thompson Scattering). Scattering by a Bound electron (Rayleigh scattering).

**3. Inhomogeneous wave equation**: Electromagnetic potential and gauges: Electromagnetic potentials, Non-uniqueness of electromagnetic potential and gauge transformation on: Coulomb gauge; solution of inhomogeneous wave equations, Refracted and advanced pofertial: solution of inhomogeneous wave equation by Fourier analysis. Electromagnetic potentials in uniform electric and magnetic fields; calculation of electromagnetic fields by using electromagnetic potential.

**4. Magneto-hydrodynamics and plasma physics:** Domains of magneto-hydrodynamics and plasma plysics; Electrical neutrality in a plasma, Debye Screening distance; Magneto-hydrodynamic equations,, plasma oscillations and Alfren waves.

**MTA 519 : AERODYNAMICS 4 credits**

**1. Preliminary Notions:** Aerodynamic force, lift and Drag. Chord of a Profile, Chord of an Airfoil. Aspect ratio, Geometrical incidence / Angel of attack.

2. **Thermodynamic Conception:** Thermodynamic State. Variables of state, Equation of state, the First Principal law of Thermodynamics. the concept of Entropy, The Second law. The Canonical equation of state. Free Energy and Free Enthalpy.

3. **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.

4. **Two-Dimensional Motion:** Oblique Shock waves, Supersonic Flow over a wedge, Mach lines: the Prandtl-Meyer function, Reflection of Oblique shocks. Mach reflection.

5. **The General Equation of a Frictionless Flow of a Gas**: The Continuity. Momentum and Energy Equations, The Eulerian Derivative. Natural coordinates, Crocco's Theorem.

6. **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.

7. **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.

8. **Transonic Flow:** Concept of transonic flow. Transonic range, Transonic flow past a wedge sections, the hodograph transformations and applications to non-linear transonic flow field.

9. **The Method of Characteristics:** Hyperbolic equations, The compatibility relation. Axially symmetric flow, Non-isentropic flow, Intersection of waves.

*Reference Books:*

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

## MTA 520: DYNAMICAL METEOROLOGY

**4 credits**

1. Thermodynamics of atmosphere: Equation of state of dry and moist air. Adiabatic changes of dry air and most air.

2. Applications of thermodynamics to the atmosphere.

3. Atmospheric radiation: Radiative transfer, Structure and absorption of infra-red-bands (absorption of spatial lines. bound spectrum. pressure and temperature corrections, water vapour spectrum, spectra of other atmospheric gases).

4. Measurement of atmospheric emission.

5. Equations of motion of the atmosphere. Simple atmospheric motions.

6. Surfaces of discontinuity. Kinematical analysis of the pressure field.

7. Atmospheric turbulence. Turbulent mass exchange, the energy of atmospheric motions, perturbation theory of atmospheric motion.

8. Quasigeostropic system of equation. Air masses: Fronte, Cyclones and anticyclones.

## MTA/MTP 521: DIFFERENTIAL AND INTEGRAL EQUATIONS

**4 credits**

1. **Existence and uniqueness theorem for differential equations:** Methods of successive approximations, Peano's existence theorem, fixed point methods, Continuation of solutions.

2. **System of differential equations**: Linear systems and their solutions by eigenvalue methods, variation of parameters, Exponentials with applications.

3. **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.

4. **Stability theory:** Stability of Linear and nonlinear systems of differential equations and Volterra integral equations, Liapunov functions and determinations of stability.

5. **Periodic solutions:** Periodic solutions of Linear and nonlinear differential and Intergral equations.

***Reference Books:***


1. Morris W. Hirsch and Stephen Smale. Differential Equations, Dynamical systems and Linear Algebra; Academic press. New York, 1974.
2. Driver, R.D, Introduction to Ordinary Differential Equations.
3. June Cronin, Differential Equation. 1980.
4. T.A. Burton, Stability and periodic solutions of ordinary and functional differential equations; Academic Press. New York. 1985.
5. Rama Mohana Rao, Ordinary differential equations, theory and applications. East-West press pvt. Ltd, 1980

## MTA/MTP 522: OPERATIONS RESEARCH

**4 credits**

1. **Basics of Operations Research:** Introduction, Definition. Characteristic. Necessity. Scope, Classification of problems, Types of mathematical models. Review of Linear Programming.

2. **Transportation and Assignment problem:** Introduction, Formulation. Relationship with LP, Solution procedure and Applications.

3. **Network Models:** Network definitions, Shortest Route problem, Minimal Spanning Tree problem and Maximal-Flow problem.

4. **Integer programming:** Introduction. Branch and Bound Algorithm, Cutting-plane Algorithm, Application.

5. **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.

6. **Matrix Game Theory:** Introduction. Minimax-maximin pure strategies. Mixed strategies and Expected payoff, solution of *2X2* games, solution (2Xn) and (mX2) games. solution of (mX2n) games by linear programming and Browns algorithm.

7. **Dynamic Programming:** introduction, Investment Problem, production scheduling problem. Stagecoach problem, Equipment replacement problem.

8. **Nonlinear Programming:** Introduction, Unconstrained problem, Lagrange method for equality constraint problem, Kuhn-Tucker method for inequality constraint problem and Quadratic programming problem.

*Reference Books:*

1. Hamdy. A. Taha. Operation Research.
2. A. Ravindran, D.T. Phillips, .1.J. Solberg. Operations Research.
3. B.E. Gillett. Introduction to Operations Research.
4. Anderson, Sweeney, Williams. An Introduction to Management Science.

## MTA/MTP 523: NUMERICAL METHODS FOR DIFFERENTIAL EQUATIONS 4 credits

### Finite Element Method

**1. Introduction to FEM:** Discretization, Construction of basis functions. Numerical integration; coordinate transformation, local and global derivatives, mesh generation. h-p convergence, finite element approximation of line and double integrals,

**2. Method of Weighted Residuals:** Subdomain, Collocation, Galerkin, and Least-Squares methods. Matrix Formulation; Modified Galerkin techniques, Element/ stiffness matrix.

**3. Finite element solution of BVP:** Outline of FE procedures for I-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).

**4. Variational Formulation of BVP:** Functional and Variational Calculus. Construction of Functionals, Rayleigh Ritz Method and Finite elements.

### Finite Difference Method

**5. Review** of Finite difference approximation. Applications to solve eigenvalue problems and higher order BVP.

**6. Elliptic PDEs:** Difference equations for Poisson's and Laplace's Equations BVP, matrix formulation, Convergence by iterative methods, and error analysis.

**7. 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.

**8. Hyperbolic problems:** Difference methods for a scalar IVP and IBVP, Lax-Wendroff and Courant-Friedrichs-Lewy explicit methods. Wendruoff implicit method, Wave Equation in time dependent and two space dimension. Convergence and stability analysis.

***Reference Books:***


1. P.E. Lewis and J.P Ward - The finite element method; Principles and Application, Addison-Wesley, 1991.
2. O.C. Zienkiewicz and K. Morgan- Finite Elements and approximations. John Wiley and Sons. 1993.
3. M.A. Celia and W.G. Gray- Numerical Methods for Differential Equations, Prentice-Hall Int. Inc., 1992.
4. G.D. Smith - Numerical solution of Partial differential equations, Clarendon press. Oxford,1978.
5. Paul D. and David Zachmann -- Applied Partial Differential Equations, Harper & Row Publications, New York, 1989.


## MTP / MTA 524: GEOMETRY OF DIFFERENTIAL MANIFOLDS
**4 credits**

**1. 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 Egreegium, fundamental theorem of surface theory,

2. **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.

3. **Geodesics on a surface:** Geodesics, differential equation of geodesics, geodesics on plane, surface, sphere, right circular cone, right helicoid, cylinder, torus etc., geodesic curvature $\kappa_g$ 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.

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

5. **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 manifolds.

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

7. **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.

**8. Vector fields on a manifolds:** Cα 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 related vector fields.

***Reference Books:***


1. C. E. Weatherburn, 1939. Differential Geometry of Three Dimensions. Cambridge University press, London.
2. D. J. Struik, 1961. Lectures on Classical Differential Geometry, Addison-Wesley Publishing Company, Inc. U.S.A.
3. F. Brickell and R. S. Clark, 1970. Differentiable Manifolds: An Introduction. Van Nostrand Reinhold Company, London.
4. F. W. Warner, 1971. Foundations of Differentiable Manifolds and Lie groups, Scott, Foresman and Company, Glenview. Illiniois, London.
5. F. W. Warner, 1971. Foundations of differentiable Manifolds and Lie groups. Scott, Foresman and Company, Glenview. Illiniois. London.


## MTA/MTP 525: ASYMPTOTIC AND PERTURBATION THEORY **4 credits**

1. 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.

2. Expansion of Integrals: Integration by parts. Laplace's method and Watson's Lemma, method of steepest descents, method of stationary phase.

3. Transform integrals and their asymptotic evaluation.

4. Differential Equations: Singularities and asymptotic

methods of solutions with a large or small parameter (WKB method), Transition points.

5. Asymptotic matching: Use of asymptotic matching for expansion of integrals.

6. Straightforward expansions of sources of non-uniformity.

7. The method of strained co-ordinates.

8. The method of matched and composite asymptotic expansions.

*Reference Books*:


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


**MTA/MTP 526: DYNAMICAL SYSTEMS 4 credits**

**1. 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.

**2. 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.

**3. 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, Smale horseshoe map, expanding map.

**4. 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.

**5. Bifurcations:** Bifurcations, bifurcation points, bifrucation of quadratic maps. saddle-node, period doubling, pitchfork, transcritical bifurcation, bifurcation diagram.

**6. Symbolic dynamical systems:** Sequence spaces, shift map, properties of shift maps, symbolic dynamics, itinerary, sub shift of finite type.

**7. Fractals:** The chaos game. Cantor set revisited. Sierpinski triangle, Koch snowflake, topological dimension, fractal dimension.

***Reference Books:***


1. A. Katok and B. Hasselblatt. Introduction to modern theory of dynamical systems. Cambridge University Press, Cambridge 1995.
2. R.L. Devaney. A First course in chaotic dynamical systems, Westview Press 1992.
3. R.A. Holmgren. A first course in discrete dynamical systems, Springer 2001.
4. K.L. Alligood, T.D. Sauer. Chaos: An introduction to dynamical systems, Yorke 1990.
5. K. Falconer. The geometry of fractal sets, Cambridge University Press. Cambridge 1985.


## MTA/MTP 527: MATHEMATICAL BIOLOGY

**4 credits**

**1. 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.

**2. Stochastic Model:** Stochastic linear and nonlinear models of population, spatial model, optimal control of population model.

**3. Microbial population models:** Micobial population, Chemostat, growth of microbial populations, stability of the models.

**4. Virus dynamics:** Virus, immunity, cells, epidemic models, dynamics of infections diseases, AIDS/HIV models, dynamics of hepatitis B virus, age-dependent epidemic model, stochastic epidemic model.

**5. Anti-Virus drug therapy:** Control of an epidemic model, drug therapy, vaccination effects, treatment of H1V, CTL response, immune responses eliminate infected cell, simplest models of immune response dynamics.

**6. Dynamics with diffusion:** Diffusion equation, single and multi-species diffusion models, competition model with diffusion, epidemic model with diffusion, diffusion in artificial kidney.

**7. Applications:** Blood pressure and its measurements, glucose concentration in blood, heart function test, and optimization models for blood testing.

***Reference Books:***


1. J.D. Murry. Mathematical Biology. Springer. 1993.
2. J.N Kapur, Mathematical Models in Biology and Medicine. 1990.
3. Edward Beltrami. Mathematics for Dynamic Modeling, 1987.

4. Leah Edelstein-Keshet, Mathematical Models in Biology. 1988.
5. M. A. Nowak, R. M. May. Virus Dynamics, Mathematical Principles of Immunology and Virology. 2000.

## MTA/MTP 528: RIEMANNIAN GEOMETRY

**4 credits**

**1. Introduction:** Fundamental notions, Non-Euclidean geometry, symmetric spaces, Riemannian manifolds, Riemannian submanifolds, Pseudo-Riemannian manifolds.

**2. 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.

**3. 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.

**4. 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.

**5. Metrics and Connections:** Metrics and connections on bundles, Riemannian metrics, Affine connection, torsion and curvature tensors. Parallel transport, Geodesics, Levi-Civita connection, Coordinate representation of the curvature tensor.

**6. 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.

Fundamental theorem of Riemannian geometry.

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

**8. Contact Geometry:** Contact structure, Contact space, contact manifolds, Durboux theorem on contact manifold, complex manifolds, complex projective space. theorem on complex contact manifolds.

***Reference Books:***

1. C. S. Isham, Modern Differential Geometry, World Scientific, 1999.
2. V. I. Arnold. Mathematical Methods of Classical Mechanics, Springer- Verlag, 1978.
3. W. H. Chen. S. S. Chern and K. S. Lam, Lectures on Differential Geometry, World Scientific, 2000.
4. R. W. R. Darling, Differential Forms and Connections. Cambridge University Press, 1994.
5. R. O. Wells Jr., Differential Analysis on Complex Manifolds, Springer-Verlag)1991.
6. T. Frankel, The Geometry of Physics: An introduction, Cambridge University Press, 1997.

## MTA/MTP 529: OPERATIONS MANAGEMENT

**4 Credits**

**1. Introduction:** Introduction to Operations Management, The scope of OM, OM and decision making Productivity, Product mix, Strategy, Competitiveness.

**2. Capacity Planning:** Strategic capacity decision, Strategy formulation, Defining and measuring capacity, Evaluating capacity alternatives.

**3. Quality Control:** Management of quality, Statistical process control, Variations and control, Control Charts. Process capabilkit, Improving proces capability, Capability analysis.

**4. Forecasting:** Features common to all forecasts, Elements of good forecast, Steps in the forecasting process, Accuracy and control of forecasting, Applications Forecasting models.

**5. Inventory Control:** Nature and importance of inventories. Introduction to basic inventory models (Economic order quantity (*EOQ) model, EPQ model. Fixed order interval model, Single period model.

**6. Scheduling:** Scheduling in high-volume systems, intermediate-volume systems, low-volume systems, Scheduling methods of Linear Programming Scheduling jobs through two work centers, Minimizing scheduling difficulties. Scheduling the work force.

**7. Simulation:** Basic terminology of simulation, steps in simulation process, Application of simulation, Simulation with random variables, Advantage and limitations of using simulations.

**8. 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 estimates, Applications.

***Reference Books:***

1. William. J. Stevenson, Operations Management.
2. Wayne L. Winston, Operations Research.
3. Hiller and Lieberman. Introduction OR.

## MTA/MTP 530: SPECIAL TOPICS 4Credits

Detailed syllabus will be given by the Department.

# University of Dhaka
# Department of Mathematics
# Syllabus for M. Phil./Ph. D. Courses
# for the Sessions 2009-2010 to 2011-2012.

Every student registered in the First Year M. Phil. Program of the Department of Mathematics during the session 2009-2010 to 2011-2012 will have to take 4 (four) half units courses listed below as advised by the concerned supervisor subject to the approval of the Academic Committee. At the end of the first year program, he/she will have to appear at written examination in the courses offered, one course comprising 50 marks and three hours duration in the examination. There will also be a viva voce examination carrying 100 marks. The minimum qualifying marks in each paper is 60 percent.

Ph. D. Program student will have to take 4 (four) half units courses listed below as advised by the concerned supervisor subject to the approval of the Academic Committee.

| Course No. | Course Name |
|---|---|
| MPH 1001 | Group Theory |
| MPH 1002 | Functional Analysis |
| MPH 1003 | Delay Differential and Volterra Equations |
| MPH 1004 | Mathematical Modeling in Biology |
| MPH 1005 | Chaotic Dynamical Systems |
| MPH 1006 | Numerical Methods for Partial Differential Equations |
| MPH 1007 | Foundation of Riemannian Manifolds |

| | |
|---|---|
| MPH 1008 | Finite Element Method |
| MPH 1009 | Advanced Topics in Operations Research |
| MPH 1010 | Convection Heat Mass Transfer |
| MPH 1011 | Classical field Theory |
| MPH 1012 | Methods of Classical Mechanics |
| MPH 1013 | Quantum Mechanics |
| MPH 1014 | Watershed Hydrology Modeling |
| MPH 1015 | Hydrodynamic And Kinematic Hydrology And Modeling |
| MPH 1016 | Ground Water Flow Models of Hydrology |

**MPH 1001: Group Theory**

1. Extension of Groups: direct sum, direct product, split extension.
2. Finitely generated Abelian Groups.
3. Groups of prime order: The Frattini subgroups, p'-automorphism of p-groups and of Abelian p-groups.
4. Simple Groups of low ran: Groups of odd order, Groups with Dihedral sylow 2- subgroups, Groups with Abelian Sylow 2-susbgroups.
5. Soluble and Nilpotent Groups.
6. Free Groups & Free Products

**Suggested Reference Books:**

1. Fuchs - Abelian groups, Hungarian Academy of Science.
2. Gorenstein-Finite Groups, Harper & Row.

3. M. Hall- The Theory of Groups, Macmillan
4. J.D. Macdonald-The Theory of Groups, Oxford University Press.
5. D. J. S. Robinson- A Course in the Theory of Groups, Graduate Texts Mathematics, Springer-Verlag.

## MPH 1002: Functional Analysis

1. Metric space: Normed linear space, Completeness, separability and compactness.

2. Linear operators: Continuity and boundedness of linear operations, Properties of linear operators.

3. Adjoint operator: Dual of Banach spaces, Bounded self adjoint operators.

4. Compact operators: Linear compact operators, Examples of compact operators.

5. Self adjoint operators and their spectral theory.

### Suggested Reference Books:

1. V. Hudson and J. R. Pym - Application of functional analysis and operator theory
2. N. Dunford and T. T. Schwartz - Linear Operators, Inter Science
3. H.G. Heusen - Functional Analysis, John Wiley & Sons.
4. A.E. Taylor- Introduction to Functional Analysis, John Wiley & Sons.

## MPH 1003: Delay Differential and Volterra Equations

1. Systems of Ordinary Differential Equations: Review of Existence and Uniqueness Theory, Stability, boundedness, periodic and Asymptotic Behavior.

2. Delay Differential Equations: Classification, Existence, Uniqueness and Continuous Dependence, Stability, Characteristic Equations, bounded and unbounded delay.

3. Volterra Integral Equations: Existence and Uniqueness Theory, Linear and nonlinear Systems with stability and periodic solutions.

4. Volterra Integro-Differential Equations: Basic definitions and theory integro-differential equations.

**Suggested Reference Books:**

1. R. D. Driver - Ordinary and Delay Differential Equations.
2. Y. Kuang - Delay Differential Equations with Applications in Population Dynamics.
3. R. K. Miller - Nonlinear Volterra Integral Equations.
4. T. A. Burton - Stability and Periodic Solutions of Ordinary and Functional Differential Equations.

## MPH 1004: Mathematical Modeling in Biology

1. Population Model: Logistic model and its modifications, delay logistic model, stability and asymptotic behavior, interacting population model.

2. Virus Dynamics: Virus, immunity, basic models, AIDS/ HIV models, dynamics of hepatitis B virus, drug therapy.

3. Epidemic Model: Epidemic models, Epidemic models with applications, age-dependent epidemic model, Delay epidemic model with drug therapy.

4. Stochastic Model: Stochastic linear and non-linear population model, stochastic epidemic model.

5. Dynamics with Diffusion: Diffusion equation, single and multi-species diffusion models, competition model with diffusion, epidemic model with diffusion

**Suggested Reference Books:**

1. J.D. Murray - Mathematical Biology, Springer, 2002.
2. Edward Beltrami - Mathematics for Dynamic Modeling, 1987.
3. Leah Edelstein-Keshet - Mathematical Models in Biology, 1988.
4. M. A. Nowak, R.M. May- Virus Dynamics, Mathematical Principles of Immunology and Virology, 2000.

**MPH 1005: Chaotic Dynamical Systems**

1. Chaos: Sensitive dependence on initial conditions, orbit structure, Cantor set, basin of attractor & repeller, strange attractors, Lyapunov exponents, Smale- Horseshoe map.

2. Bifurcations: Basic definitions of bifurcations, bifurcation points, classification of bifurcation, bifurcation diagram.

3. Symbolic Dynamical Systems: Sequence spaces, shift map, symbolic dynamics, subshift of finite type.

4. Fractals; Cantor set, Sierpinski triangle, Koch Snowflake, iterated function systems, topological and fractal dimension.

5. Julia, Fatuo and Mandelbrot sets: Basic definitions of Julia, Fatuo and Mandelbrot sets. Computing the Filled Julia set, similarity of Mandelbrot sets.

**Suggested Reference Books:**

1. R.L. Devaey - An introduction to chaotic dynamical system, Addison-Wesley, 1987.
2. A. Katok and B. Hasselblatt - Introduction to modern theory of dynamical systems, CUP 1995.
3. K Falconer - The Geometry of Fractal set, CUP 1983.
4. R.L.Daveny and L. Keen - Chaos and Fractals: The Mathematics behind the Computer Graphics, AMS, 1989.

## MPH 1006: Numerical Methods for Partial Differential Equations

1. Introduction: Basic concepts of Partial Differential equations, Types of problems, usual method of solutions, Separation of variables, Variational methods.

2. Finite difference approximations, solution of I-D linear and nonlinear BVP, Applications to solve eigenvalue problems and higher order BVP.

3. Elliptic PDEs: The Potential Equation, Dirichlet and Neumann problems, Poisson's equation and Laplace's equation in rectangular domains. Harmonic functions. Numerical solutions of Poisson's and Laplace's Equations, matrix formulation, Convergence by iterative methods, and error analysis

4. 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.

5. Hyperbolic problems: Difference methods for a scalar IVP and IBVP, Lax-Wendroff and Courant-Friedrichs-Levy explicit methods, Wendroff implicit method, Wave Equation in time dependent and two space dimension, Convergence and stability analysis

**Suggested Reference Books:**

1. R. L. Burden and J. D. Faires - Numerical Analysis, Thomson (Brooks/Cole), 2005.
2. M.A. Celia and W.G. Gray- Numerical Methods for Differential Equations, Prentice- Hall Int. Inc., 1992.
3. D. Smith - Numerical Solutions of Partial Differential Equations, Clarendon press, Oxford, 1978.
4. D. Paul and David Zachmann - Applied Partial differential Equations, Harper & Row Publications, New York, 1989.
5. Karl E. Gustafson - Partial differential equations and Hilbert space method, John Wiley & Sons, New York, 1987.

## MPH 1007: Foundation of Riemannian Manifolds

1. Riemannian Manifolds: Manifolds, tangent space, vector fields on Manifolds, brackets on vector fields, trajectory and local flow of the vector fields, topology of manifolds.

2. Riemannian metrics: Riemannian metrics, parameterized curve, differentiable vector field, velocity field, segment and length of a segment of a Riemannian manifolds.

3. Affine and Riemannian Connections: Affine Connections, parallel vector field, parallel transport, Riemannian Connections, symmetric of affine Connection, Levi-Civita theorem on Riemannian Connections.

4. Geodesics and curvature of Riemannian Manifolds: Geodesic flow, homogeneity of a geodesic, exponential map, minimizing properties of geodesics, curvature on Riemannian manifolds, sectional curvature, Ricci curvature and scalar curvature.

5. Jacobi fields on manifolds of curvature: The Jacobi equation, Jacobi fields on constant curvature, conjugate points for Jacobi field, complete manifolds, theorem on Carton on the determination of the metric by means of the curvature, Hyperbolic space forms.

**Suggested Reference Books:**

1. C. S. Isham - Modern Differential Geometry, World Scientific, 1999.
2. F. Brickell and R. S. Clark - Differentiable Manifolds: An Introduction, Van Nostrand Reinhold Company, London, 1970.
3. L. Conlon - Differentiable Manifolds: A First Course, Birkhäuser Boston, Basel, Berlin, 1993.
4. W. B. Boothby - An introduction to Differentiable and Riemannian Geometry, Academic Press, Inc. New York, 1975.
5. W. H. Chen, S. S. Chern and K. S. Lam - Lectures on Differential Geometry, World Scientific, 2000.

**MPH 1008: Finite Element Method**

1. Introduction to FEM: Discretization, Construction of basis functions, Numerical integration; coordinate transformation, local and global derivatives, finite element approximation of line and double integrals.

2. Method of Weighted Residuals: Galerkin method, Matrix Formulation; Modified Galerkin techniques, Element/stiffness matrix.

3. Finite element solution of BVP: Outline of FE procedures for 1-D BVP. Formulation, Matrix Formulation, Element concept, Assembly, Numerical examples. 1D Heat equation.

4. 2-D problems: Element concept, Triangular,

Rectangular and Quadrilateral elements (linear and quadratic elements), Assembly, Poisson's and Laplace's equations, Heat equations and wave equations, Matrix Formulation, error analysis.

5. Variational Formulation ofBVP: Functional and Variation Calculus, Construction of Functionals, Rayleigh Ritz Method and Finite elements, Maximum principle.

6. Numerical solutions of 1D and 2D problems using higher order finite elements and its implements in Mathematica/MathLab programming.

**Suggested Reference Books:**


1. P.E. Lewis and J.P Ward - The Finite Element Method; Principles and Application, Addison-Wesley, 1991.
2. O.C. Zienkiewicz and K. Morgan- Finite Elements and Approximations, John Wiley and Sons, 1993.
3. J.N. Reddy - An Introduction to the Finite Element Method, McGraw-Hill Int. Editions, 1993.
4. Pavel Solin - Partial differential equations and the Finite Element Method, Wiley Interscience, 2006.
5. A. I. Beltzer - Variational and Finite element methods, Springer-Verlag, 1990.


**MPH 1009: Advanced Topics in Operations Research**

**Chapter 1:** Introduction

**Chapter 2:** Revised simplex method

**Chapter 3:** Column generation to solve large problems.

**Chapter 4:** Decomposition techniques and pricing

**Chapter 5:** Decision making under uncertainty

**Chapter 6:** Forecasting

**Chapter 7:** Fractional programming

## Suggested Reference Books:

1. W.L. Winston - Operations Research: Applications and algorithms.
2. Hiller and Lieberman - Introduction to operations research.
3. C. Van De Panne - Method for LPs and QPs.

## MPH 1010: Convection Heat Mass Transfer

**1. Basic:** .Fundamental problem in convective head and mass transfer, concept of Boundary layer, velocity, thermal and mass boundary layers, similarity solutions, natural convection, mass conservation, mass diffusivities, laminar forced convection.

**2. Forced Convection:** Plane wall with constant temperature/constant heat/mass flux, sphere and cylinder: Boundary layers. Point source and line source: Thermal wakes, Transient effects, Effects of Inertia and Thermal Dispersion: plane wall. Effects of boundary friction and porosity variation: plane wall.

**3. Natural Convection:** Scale analysis Vertical plate, horizontal plate, inclined plate, Horizontal cylinder/sphere, vertical cylinder/cone, Non Darcy effects and the effects of Dispersion, Darcy flow between isothermal side walls.

**4. Mixed Convection:** Inclined or vertical plane wall, Horizontal wall, Cylinder or sphere, other Geometries.

**5. Convection in porous Media:** Darcy flow model and the forchheimer Modification, forced convection, Natural convection Boundary layers.

## References:

1. Adrian Bejan - Convection heat transfer
2. L. C. Burmeister - Convective heat transfer

3. D. A. Nield and A. Bejan - Convection in porous media
4. Frank P. Incropera - Fundamentals of Heat and Mass transfer

**MPH 1011: Classical Field Theory**

1. Special theory of Relativity.

2. Relativistics mechanics

3. Maxwell's equations, Relativistic electrodynamics, electromagnetic radiation.

4. Riemamm and Ricci tensors, principle of Equivalence and Einstein Equations, Schwarzschild solution and its properties, spherically symmetric solutions Gravitational collapse, Kerr solution and its properties, Ernst solutions and its properties, Weyl's solutions and its properties.

5. Robertson-Walker line elements, Friedmann and Hamaitre cosmological models. Introduction to Penrose-Hawking singularity theorems. Introduction to inflationary cosmologies.

**Suggested Reference Books:**

1. D. J. Griffiths - Introduction to Electrodynamics, 3rd Ed.
2. J.D. Jackson - Classical Electrodynamics
3. J.N. Islam - Rotating Fields in general Relativity.
4. A.K. Raychaudhuri - Theoretical Cosmology.
5. Gibbons. Hawking & Siklos (Eds) - The very early Universe.

**MPH 1012 : Methods of Classical Mechanics**

1. Kepler's Laws of planetary motion, Precession & Nutrition of the planet, landing of the Moon. (Mathematical Modeling)

2. Lagrange Mechanics.

3. Hamilton's Mechanics.

4. Euler-Lagrange variational Mechanics.

5. Solution of Laplace equation.

6. Spherical Astronomy (Elements of celestial Mechanic).

**Suggested Reference Books:**

1. L. A. Pars: Analytical Dynamics.
2. Smart: Spherical Astronomy.

**MPH 1013: Quantum Mechanics**

1. Dynamical variable and observables.

2. Representations equations of motion in different picture (Schrodinger, Heisenberg and interaction).

2. Operation methods in quantum mechanics, symmetries.

3. Addition of angular momentums (Elebsch-Gordon coefficients, irreducible tensor operators, Wigner-Echart theorem).

4. Time dependent and time independent perturbation theory, variational method, green's function method of solution, Lippman-Schwinger equation.

6. Definition of S-matrix, T -matric.

7. Motion of an electron in magnetic field.

8. Dirac's equation, relativistic covariance of the Dirac's Hole theory, explicit solution of the Dirac equation.

**Suggested Reference Books:**

1. P.A. M. Dirac: The principles of quantum mechanics (Fourth edition).

2. Landan & Lifshitoz: Quantum mechanics (Non-relativistic).
3. K. Gottfried: Quantum mechanics, vol 1.
4. L. 1. Schiff: Quantum mechanics (Third edition).
5. Panling & Wilson: Introduction to Quantum mechanics.

## MPH 1014 : Watershed Hydrology Modelling

Introduction, Watershed Runoff and its computation, Watershed Hydrographs computation, Flood Routing, Sedimentation Climatic Reqious, Statistical and Probability Analysis of Hydrologic Data, Conceptual Models of Unit Hydrograph, Frequency Analysis, Watershed Yeld, Watershed Modelling, Application of Watershed Modelling, Nonlinear Concelptional Models, Nonlinear Black Box models, Models for Ungauned Watersheds, Linear Time-Variant Models.

## MPH 1015: Hydrodynamic And Kinematic Hydrology And Modelling

Introduction, Analysis of Runoff, Hydrogranh Shape and Flows. Hydrodynamic Assumptions of flows, Kinematic Assumption of flows, Numerical Solution of Hydrodynamic and Kinemative crave models, Dimensionless Hydrographs, Strom Dynamics and Distribution. Conduct flow, Urban Catchment Management, Hydrodynamics Modelling Kinematic Modelling, Applications of Hydrodynamic and Kinematic Modelling, The Kinematic Cascade a Hydrologic Model Open channel Hydravcs.

## MPH 1016: Ground Water Flow Models of Hydrology

Introduction, Occurrence of groundwater, g round water Movement. groundwater and well Hydrolics, groundwater levels and Environmental influences, Qualify of groundwater, Pollution groundwater, Management of groundwater, Saline water Intrusion In Aquisters of groundwater, Subsurface Investigation of groundwater, Concepts of Fluvial geomorphology of groundwater, groundwater modelling Techniques.

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