DEPARTMENT OF HIGHER EDUCATION GOVT. OF J&K

**JAMMU AND KASHMIR INSTITUTE OF**

**MATHEMATICAL SCIENCES**

**CAMPUS (A.S. COLLEGE) SRINAGAR-190008**

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**Course Structure for 7th Semester to 10th Semester onwards (CBCS Advanced)**

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| **Semester – VII** | | | | |
| **Course Type** | **Course Code** | **Title of the Course** | **No. of Credits** | **Teacher** |
| Core (CR) | IMTH701CR | Real Analysis – I | 04 |  |
| IMTH702CR | Complex Analysis – I | 04 |  |
| IMTH703CR | Topology | 04 |  |
| **IMTH 704CR** | **Mathematical Statistics** | **02** |  |
|  |  |  |  |  |
| Discipline Centric Electives  (DCE) | IMTH705DCE | Theory of Matrices | 04 |  |
| IMTH706DCE | Fourier Series, Fourier Transform and Laplace Transform | 04 |  |
| IMTH707DCE | Numerical Analysis | 04 |  |
|  |  |  |  |  |
| Generic Electives (GE) | IMTH708GE | Numerical Methods | 02 |  |
|  |  |  |  |  |
| Open  Electives (OE) | IMTH709OE | Calculus | 02 |  |
|  |  |  |  |  |

**General Instructions for the Candidates**

1. The two year (4 semester) PG programmes is of 96 credit weightage i.e., 24 credits/semester (24x4=96).
2. Out of 24 credits in a semester a candidate has to obtain 14 credits compulsorily from “**Core Courses**”, while the remaining 10 credits can be obtained from the “**Electives**” in the following manner:
   * A candidate can obtain a maximum of 8 credits within his/her own Department out of the specializations offered by the Department as **Discipline Centric-Electives**.
   * 2 credits shall be obtained by a candidate from the **Electives**

offered by the Department other than his/her own. The candidate shall be free to obtain either 2 credits from the **Generic** (within School) or two credits from **Open Electives**.

* + At least 2 credits out of 8 credits slatted for OE/GE category shall be obtained from online UGC SWAYAM platform during the 4 semester Programme.

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| **Semester – VIII** | | | | |
| **Course Type** | **Course Code** | **Title of the Course** | **No. of Credits** | **Teacher** |
| Core (CR) | IMTH801CR | Real Analysis – II | 04 |  |
| IMTH802CR | Discrete Mathematics | 04 |  |
| IMTH803CR | Complex Analysis-II | 04 |  |
| IMTH804CR | Advanced Calculus | 02 |  |
|  |  |  |  |  |
| Discipline Centric Electives (DCE) | IMTH805DCE | Theory of Numbers | 04 |  |
| IMTH806DCE | Operation Research | 04 |  |
| IMTH807DCE | Introduction to Mathematical Modeling | 02 |  |
| IMTH808DCE | Integral Equations | 02 |  |
| IMTH809D CE | Riemannian Geometry | **02** |  |
|  |  |  |  |  |
| Generic Electives (GE) | IMTH810GE | Complex Variables | 02 |  |
|  |  |  |  |  |
| Open  Electives (OE) | IMTH811OE | Matrix Algebra | 02 |  |
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| **Semester – IX** | | | | |
| **Course Type** | **Course Code** | **Title of the Course** | **No. of Credits** | **Teacher** |
| Core (CR) | IMTH901CR | Ordinary Differential Equations | 04 |  |
| IMTH902CR | Computational Mathematics with MATLAB | 04 |  |
| IMTH903CR | Functional Analysis-I | 04 |  |
|  | **IMTH904CR** | **Fourier Analysis** | **02** |  |
|  |  |  |  |  |
| Discipline Centric Electives  (DCE) | IMTH905DCE | Advanced Graph Theory | 04 |  |
| IMTH906DCE | Abstract Measure Theory | **04** |  |
| IMTH907DCE | Mathematical Biology | 04 |  |
| IMTH908DCE | Wavelet Theory | 04 |  |
|  |  |  |  |  |
| Generic  Electives (GE) | **IMTH909GE** | Artificial Intelligence | **02** |  |
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| Open Electives  (OE) | IMTH910OE | Mathematical Modelling | 02 |  |
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**General Instructions for the Candidates**

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offered by the Department other than his/her own. The candidate shall be free to obtain either 2 credits from the **Generic** (within School) or two credits from **Open Electives.**

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| **Semester – X** | | | | |
| **Course Type** | **Course Code** | **Title of the Course** | **No. of Credits** | **Teacher** |
| Core (CR) | IMTH1001CR | Partial Differential Equations | 04 |  |
| IMTH1002CR | Differential Geometry | 04 |  |
| IMTH10033CR | Advanced Abstract Algebra-II | 04 |  |
|  | **IMTH1004CR** | **Linear Algebra** | **02** |  |
|  |  |  |  |  |
| Discipline Centric Electives (DCE) | IMTH1005DCE | Analytic Theory of  Polynomials | 04 |  |
| IMTH1006DCE | Mathematical Statistics | 04 |  |
| IMTH1007DCE | Functional Analysis – II | 04 |  |
| IMTH1008DCE | Non-Linear Analysis | 04 |  |
| IMTH1009DCE | Advanced Topics in Topology and Modern Analysis | 04 |  |
| IMTH1010DCE | Project | 04 |  |
|  |  |  |  |  |
| Open Electives  (OE) | **IMTH1011OE** | **Discrete Mathematics** | **02** |  |
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**General Instructions for the Candidates**

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   * A candidate can obtain a maximum of 8 credits within his/her own Department out of the specializations offered by the Department as **Discipline Centric-Electives**.
   * 2 credits shall be obtained by a candidate from the **Electives** offered by the Department other than his/her own. The candidate shall obtain 2 credits from the **Generic** (within School).
   * At least 2 credits out of 8 credits slatted for OE/GE category shall be obtained from online UGC SWAYAM platform during the

4 semester Programme.

**The Academic Tour shall be conducted by the Department every year for outgoing students (10th semester).**

Semester-VII

Core CR

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|  | **REAL ANALYSIS – I** |  |
| Course No: **IMTH701CR** |  | Total Credits: **04** |
| Examination: |  | Total Marks: 100 |
| (a). Assessment |  | Max. Marks: 20 |
| (b). Theory |  | Max. Marks: 80 |
| Time Duration: 2 ½ hrs |  | Min. Pass Marks: 40 |

**Objectives:** To study the behavior and properties of real numbers, sequences and series of real numbers and real valued functions and generalized integration in order to tackle daily life problems arising from physical phenomenon.

**UNIT-I**

Integration : Definition and existence of Riemann – Stieltje’s integral , behavior of upper and lower sums under refinement, necessary and sufficient conditions for RS-integrability of continuous and monotonic functions, reduction of an RS-integral to a Riemann integral, basic properties of RS-integrals, differentiability of an indefinite integral of continuous functions, the fundamental theorem of calculus for Riemann integrals.

**UNIT-II**

Improper integrals: integration of unbounded functions with finite limit of integration, comparison tests for convergence, Cauchy’s test, infinite range of integration, absolute convergence, integrand as a product of functions, Abel’s and Dirichlet’s test.

Inequalities: arithmetic-geometric means equality, inequalities of Cauchy Schwartz, Jensen, Holder & Minkowski, inequality on the product of arithmetic means of two sets of positive numbers**.**

**UNIT-III**

Infinite series: Carleman’s theorem, conditional and absolute convergence, multiplication of series, Merten’s theorem, Dirichlet’s theorem, Riemann’s rearrangement theorem. Young’s form of Taylor’s theorem, generalized second derivative, Bernstein’s theorem and Abel’s limit theorem.

**UNIT-IV**

Sequences and series of functions: point wise and uniform convergence, Cauchy criterion for uniform convergence, Mn--test, Weiestrass M-test, Abel’s and Dirichlet’s test for uniform convergence, uniform convergence and continuity, R- integration and differentiation, Weiestrass approximation theorem, example of continuous nowhere differentiable functions.

**Recommended Books:**

* R. Goldberg, Methods of Real Analysis.
* W. Rudin, Principles of Mathematical Analysis.
* J. M. Apostol, Mathematical Analysis.
* S.M.Shah and Saxen, Real Analysis.
* A.J.White, Real Analysis , An Introduction.
* L.Royden, Real Analysis.
* S.C.Malik and Gupta, Real Analysis.

**Complex Analysis-I**

Course No: **IMTH702CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**UNIT*-I*:**

Functions of a complex variable, Limits, Continuity, Differentiability, Cauchy-Riemann Equations and their applications, Analytic function, Harmonic function, The functions like

𝑒𝑧, 𝑠𝑖𝑛 𝑧, 𝑐𝑜𝑠 and the complex logarithm. Contour integral, Cauchy’s theorem, Cauchy- Goursat’s theorem, Cauchy’s integral formula, Higher order derivatives, Morera’s theorem,

Cauchy’s inequality, Liouville’s theorem and its applications, Winding numbers-index of a point with respect to a closed curve.

***UNIT-II:***

Power Series, Radius of convergence of a power series, Cauchy’s-Hadamard formula for finding radius of convergence, Taylor theorem, Taylor’s series, Expansion of analytic functions in a power series, Laurent’s series, Singular Points, Isolated singularities, Poles and essential singular points, Behavior of functions at infinity, Casorati – Weirestrass’s Theorem.

***UNIT-III:***

Bilinear transformations- Properties and Classification, Fixed Points, Cross ratios, Inverse points and Critical points. Conformal mapping, Mappings of: Upper half plan on to unit disc, Unit disc onto unit disc, left half plan on to unit disc, Circle onto circle. The transformations:

𝑤 = √, 𝑎𝑛𝑑 𝑤 = 𝑧2, 𝑤 =  (𝑧 + 1/𝑧).

***UNIT-IV****:*

Residues: Cauchy’s residue theorem and its applications, Calculation of residues, Evaluation of definite integrals by the method of residues, Perceval’s identity. Branches of many valued functions with reference to 𝐴𝑟𝑔 (𝑧), (𝑧), 𝑧𝑎. Infinite products, Convergence and divergence of infinite products.

**Recommended Books:**

1. L. Ahlfors, Complex analysis
2. Richard Silverman, Complex Analysis
3. S. Ponnusamy, Foundations of Complex analysis
4. J.B. Conway, Functions of a complex variable-I

**References:**

1. Z. Nihari, Conformal mapping.
2. E.C. Titchmarsh, Theory of functions

**TOPOLOGY**

Course No: **IMTH703CR** Total Credits: **04**

Examination: Total Marks: 100

(a). Assessment Max. Marks: 20

(b). Theory Max. Marks: 80

Time Duration: 2 ½ hr Min.Pass Marks: 40

**Objectives:** In inculcate the students to study the properties that are preserved through deformations, twisting and stretching of objects without tearing.

**UNIT-I**

Review of countable and uncountable sets, Schroeder-Bernstein theorem, axiom of choice and its various equivalent forms, definition and examples of metric spaces, open and closed sets, completeness in metric spaces, Baire’s category theorem, and applications to the (1) non-existence of a function which is continuous precisely at irrationals (ii) impossibility of approximating the characteristic of rationals on [0, 1] by a sequence of continuous functions.

**UNIT -II**

Completion of a metric space, Cantor’s intersection theorem with examples to demonstrate that each of the conditions in the theorem is essential, uniformly continuous mappings with examples and counter examples, extending uniformity continuous maps, Banach’s contraction principle with applications to the inverse function theorem in R.

**UNIT T-III**

Topological spaces; definition and examples, elementary properties, Kuratowski’s axioms, continuous mappings and their characterizations, pasting lemma, convergence of nets and continuity in terms of nets, bases and sub bases for a topology, lower limit topology, concepts of first countability, second countability, separability and their relationships, counter examples and behavior under subspaces, product topology and weak topology, compactness and its various characterizations.

**UNIT -IV**

Heine-Borel theorem, Tychnoff’s theorem, compactness, sequential compactness and total boundedness in metric spaces, Lebesgue’s covering lemma, continuous maps on a compact space, separation axioms Ti *i*=1,2,3,3,4) and their permanence properties, connectedness, local connectedness, their relationship and basic properties, connected sets in R, Urysohn’s lemma, Urysohn’s metrization theorem, Tietize’s extension theorem, one point compactification.

**Recommended Books:**

* 1. G.F.Simmons, Introduction to Topology and Modern Analysis.
  2. J. Munkres, Topology.
  3. K.D. Joshi, Introduction to General Topology.
  4. J.L.Kelley, General Topology.
  5. Murdeshwar, General Topology.
  6. S.T. Hu, Introduction to General Topology.

**MATHEMATICAL STATISTICS**

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| Course No: **IMTH 704CR** |  | Total Credits: **02** |
| Examination: |  | Total Marks: 50 |
| (a). Assessment |  | Max. Marks: 10 |
| (b). Theory |  | Max. Marks: 40 |
| Time Duration: 2 ½ hrs |  | Min.Pass Marks: 20 |

**Objectives:** To provide the student with a solid grounding in probability theory and mathematical statistics for predictions and decisions making.

**UNIT -I**

Interval estimation, confidence interval for mean, confidence interval for variance, confidence interval for difference of means and confidence interval for the ratio of variances, point estimation, sufficient statistics, Fisher-Neyman criterion, factorization theorem, Rao- Blackwell theorem, best statistic (MvUE), Complete Sufficient Statistic, exponential class of pdfs.

**UNIT -II**

Rao-Crammer inequality, efficient and consistent estimators, maximum likelihood estimators (MLE’s), testing of hypotheses, definitions and examples, best or most powerful (MP) tests, Neyman Pearson theorem, uniformly most powerful (UMP) tests, likelihood ratio test, chi-square test.

**Recommended Books**

* 1. Hogg and Craig, An Introduction to Mathematical Statistics.
  2. Mood and Grayball, An Introduction to Mathematical Statistics.

**References**

1. C. R. Rao, Linear Statistical Inference and its Applications.
2. V. K. Rohatgi, An Introduction to Probability and Statistics.

**Discipline Centric Electives (DCE)**

**THEORY OF MATRICES**

Course No: **IMTH705DCE** Total Credits: **04**

Examination: Total Marks: 100

(a). Assessment Max. Marks: 20

(b). Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min. Pass Marks: 40

**Objectives:** To inculcate the students to understand and apply the techniques of matrices like linear transformations from a vector space to itself such as reflection, rotation and sharing to solve multivariate problems arising in different disciplines of science and technology.

**UNIT-I**

Eigen values and eigen vectors of a matrix and their determination, similarity of matrices, two similar matrices have the same eigen values, algebraic and geometric multiplicity, necessary and sufficient condition for a square matrix of order n to be similar to a diagonal matrix, orthogonal reduction of real matrices.

**UNIT-II**

Orthogonality of the eigen vectors of a Hermitian matrix, the necessary and sufficient condition for a square matrix of order n to be similar to a diagonal matrix . If A is a real symmetric matrix then there exists an orthogonal matrix P such that P 1 AP = P`AP is a diagonal matrix whose diagonal elements are the eigen values of A, semi–diagonal or triangular form, Schur’s theorem, normal matrices, necessary and sufficient condition for a square matrix to be unitarily similar to a diagonal matrix.

**UNIT-III**

Quadratic forms: the Kroneckers and Lagranges reduction, reduction by orthogonal transformation of real quadratic forms, necessary and sufficient condition for a quadratic form to be positive definite, rank, index and signature of a quadratic form. If A=[a *ij* ] is a positive definite matrix of order n, then

|A|≤ a 11 a 22 …a *nn* .

**UNIT IV**

Gram matrices: the Gram matrix BB` is always positive definite or positive semi-definite, Hadamard’s inequality, If B=[b *ij* ]is an arbitrary non- singular real

*n n*

square matrix of order n, then |B| ≤

[ *bik* ],

functions of symmetric

*i* 1 *k* 1 .

matrices, positive definite square root of a positive definite matrix, the infinite n-fold integral

*I*      *e* *X* *AX dX* ,

*n*   

  

* n* / 2

where

*dX*  *dx*1*dx*2 *dxn* . If A is a positive definite matrix, then

*I n* 

.

*A* 1/ 2

If A and B are positive definite matrices, then

perturbation of roots of polynomials, companion matrix, Hadamard’s theorem, Gerishgorian Disk theorem, Taussky’s theorem

**Recommended Books:**

1. Richard Bellman, Introduction to Matrix Analysis, McGraw Hill Book Company.
2. Franz E. Hohn, Elementary Matrix Algebra, American Publishing company Pvt. Ltd.
3. Shanti Narayan, A Text Book of Matrices, S. Chand and Company Ltd.
4. Rajendra Bhatia, Matrix Analysis, Springer.

*A*  (1  **)*B* 

*A  B* 1**

for 0≤λ≤1,

**Fourier Series, Fourier Transform and Laplace Transform**

Course No: **IMTH706DCE** Total Credits: **04**

Examination: Total Marks: 100

(a). Assessment Max. Marks: 20

(b). Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min. Pass Marks: 40

**UNIT-I**

**Fourier Series**: Introduction, Periodic functions: Properties, Even & Odd functions. Special wave forms: Square wave, Sawtoothed wave, Triangular wave. Euler’s Formulae for Fourier Series, Fourier Series for functions of period 2π, Fourier Series for functions of period 2L, Dirichlet’s conditions, Sum of Fourier series. If f(x) is bounded and integrable function on (-, ) and if an, bn are its Fourier coefficients, then  (an2 +bn2) converges. Half Range Series for sine and cosine functions, examples. Riemann Lebseque theorem.

**UNIT -II**

**The Fourier Transform**. Periodic functions, Definition and examples of Fourier series, Drichlet’s conditions, determination of Fourier coefficients, even and odd functions and their Fourier expansion, change of interval, half range series.

Fourier transform, inverse Fourier transform, Fourier sine and cosine transforms and their inversion, properties of Fourier transforms, Fourier transform of the derivative, convolution theorem, discrete Fourier transform and fast Fourier transform and their properties.

**UNIT-III**

**Laplace Transform.** Definition, Laplace transform of elementary functions, Properties of Laplace transforms viz Linearity, translation, Change of Scale property etc. Laplace transform as periodic functions, Dirac-Delta function, Inverse Laplace transform, Laplace transform for derivatives, Laplace transform for integrals, Convolution theorem, Solution of ordinary differential equations with constant coefficients, Applications of partial differential equations.

**UNIT-IV**

Application of Laplace Transform to differential equation and integral equation, Application of Laplace Transform to boundary value problems: Electrical circuits, dynamics, Beams, Heat conduction equationsand wave equations.

**Recommended Books:**

* 1. **Churchill,** “Fourier Series & Boundary Value Problems”
  2. **Davies, Brian**, Integral Transforms and Their Applications, Springer
  3. **Erwin, Kreysigz**, Advanced Engineering Mathematics, Willey Eastern Pub.,
  4. **K.S. Rao,** Introduction to Partial Differential Equations, K.S. Rao, PHI, India.
  5. Murrey R. Spiegel, Laplace Transforms, Schaum’s outline series.
  6. I. N. Sneddon: The use of Integral Transforms, McGraw-Hill, Singapore 1972.
  7. R. R. Goldberg, Fourier Transforms, Cambridge University Press, 1961.
  8. D. Brain, Integral Transforms and their applications, Springer, 2002.

**NUMERICAL ANALYSIS**

Course No: **IMTH 706 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To provide the student with different techniques in order to find approximate numerical solutions to the problems where exact solutions are not available.

**UNIT-I**

Introduction to numerical methods, Bisection method, Method of False position, Secant method, Method of iterations, Newton-Raphson method, Ramanunjan’s method, Convergence of iteration methods, Solution of system of linear algebraic equations: Dircet methods, Matrix inverse method, Gaussian elimination method, Gauss Jacobi, Eigen value problem.

**UNIT-II**

Finite difference operators: Backward, Forward and Central difference operators, Shift operator, Relation between operators, Interpolations with equal and unequal intervals, Newton’s forward interpolation formula, Lagrange’s and Hermite interpolation formula, Linear and quadratic spline interpolations.

**UNIT-III**

Numerical differentiation, Formulae for derivatives, Derivative using Newton’s forward interpolation formula, Difference interpolating formula, Maxima and minima of tabulated functions.

Numerical integration, Trapezoidal rule, Simpson’s one-third rule, Boole’s rule, Errors in numerical integration formula.

**UNIT-IV**

Numerical solution for the initial value problems for ODE’S, Taylor’s series method, Euler’s method, Runge-Kutta Method, Picard’s method of successive approximations, Boundary value problems in PDE’s, Finite difference methods for solution, Classification of second order PDE’s, Finite difference approximations for partial derivatives, Solution of one-dimensional Laplace, Heat and wave equations.

**References:**

* 1. M.K.Jain, S.R.K.Iyengar, R.K.Jain, Numerical methods for scientific and engineering computation, New Age International Publishers.
  2. S.S.Sastry, Introductory methods of numerical analysis, PHI Learning.
  3. B.S.Grewal, Numerical methods in engineering & science, KHANNA PUBLISHERS.

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|  | **Generic Electives (GE)**  **NUMERICAL METHODS** |  |
| Course No: **IMTH 708GE** |  | Total Credits: **02** |
| Examination: |  | Total Marks: 50 |
| (a). Assessment |  | Max. Marks: 10 |
| (b). Theory |  | Max. Marks: 40 |
| Time Duration: 2 ½ hrs |  | Min.Pass Marks: 20 |

**Objectives:** To provide the student with different techniques in order to find approximate numerical solutions to the problems where exact solutions are not available.

**UNIT -I**

Solution of algebraic and transcendental and polynomial equations, bisection method, iteration method based on first degree equation, secant method, regula-falsi method, Newton-Raphson method, rate of convergence of Newton- Raphson method & secant method, system of linear algebraic equation, Gauss elimination method, Gauss Jordan method.

**UNIT -II**

Interpolation and approximation of finite difference operators, Newton’s forward, backward interpolation, central difference interpolation, Lagrange’s interpolation, Newton Divided Difference interpolation, Hermite interpolation, Spline interpolation, numerical differentiation and Integration.

**Recommended Books:**

1. M.K. Jain, Numerical solution of differential equations, Wiley Eastern (1979), Second Edition.
2. D.V. Griffiths and I.M. Smith, Numerical Methods for Engineers, Blackwell Scientific Publications (1991).

**REFERENCES:**

1. S.C. Chapra, and P.C. Raymond, Numerical Methods for Engineers, Tata McGraw Hill, New Delhi (2000)
2. R.L. Burden, and J. Douglas Faires, Numerical Analysis, P.W.S. Kent Publishing Company, Boston (1989), Fourth edition.
3. S.S. Sastry, Introductory methods of Numerical analysis, Prentice- Hall of India, New Delhi (1998).

M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical methods for scientific and Engineering computation, Wiley Eastern (1993

**Open Electives (OE)**

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|  | **CALCULUS** |  |
| Course No: **IMTH 709 OE** |  | Total Credits: **02** |
| Examination: |  | Total Marks: 50 |
| (a). Assessment |  | Max. Marks: 10 |
| (b). Theory |  | Max. Marks: 40 |
| Time Duration: 2 ½ hrs |  | Min.Pass Marks: 20 |

**Objectives:** To make the student understand the basic concepts in differentiation and integration and apply them to the day to day problems.

**UNIT -I**

Functions, the idea of limits, techniques for computing limits, infinite limits, continuity, derivative, rules for differentiation, derivatives as rate of change, applications of the derivative, maxima and minima, increasing and decreasing functions, mean value theorem and its applications, indeterminate forms, partial differentiation, Euler’s theorem.

**UNIT -II**

Indefinite integral, techniques of integration, definite integral, area of a bounded region, first Order ordinary differential equations and their salutations, variables separable method, homogeneous form, equations reducible to homogeneous form, linear differential equations of the form dy/dx +Py =Q and equations reducible to this form.

**Recommended Books:**

1. A.Aziz, S.D.Chopra and M.L.Kochar, Differential Calculus, Kapoor Publications.
2. William L.Briggs and Lyle Cochran, Calculus, Pearson.
3. S.D.Chopra and M.L.Kochar, Intgeral Calculus, Kapoor Publications.
4. R.K.Jain and S.R.K. Lyengar, Advanced Engineering Mathematics, Narosa.

**Core (CR)**

**Semester-VIII**

**REAL ANALYSIS - II**

Course No: **IMTH801CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To provide the students the notions of length, area and volume with respect to different measures viz., Lebesque and Borel measure in order to overcome problems arising from Riemann Integration.

**UNIT -I**

Measure theory: definition of outer measure and its basic properties, outer measure of an interval as its length, countable additivity of the outer measure, Borel measurable sets and Lebesgue measurability of Borel sets, Cantor set, existence of non- measurable sets and of measurable sets which are not Borel, outer measure of monotonic sequences of sets.

**UNIT -II**

Measurable functions and their characterization, algebra of measurable functions, Stienhauss theorem on sets of positive measure, Ostrovisk’s theorem on measurable solution of f (x+y)= f(x) + f(y), x, y ЄR, convergence a.e., convergence in measure and almost uniform convergence, their relationship on sets of finite measure, Egoroff’s theorem.

**UNIT -III**

Lebesgue integral of a bounded function, equivalence of L-integrability and measurability for bounded functions, Riemann integral as a Lebesgue integral, basic properties of Lebesgue –integral of a bounded function, fundamental theorem of calculus for bounded derivatives, necessary and sufficient condition for Riemann integrability on [a, b], L- integral of non- negative measurable functions and their basic properties, Fatou’s lemma and monotone convergence theorem, L–integral of an arbitrary measurable function and basic properties, dominated convergence theorem and its applications.

**UNIT -IV**

Absolute continuity and bounded variation, their relationships and counter examples, indefinite integral of an L-integrable function and its absolute continuity, necessary and sufficient condition for bounded variation, Vitali’s covering lemma and a.e., differentiability of a monotone function f and

 *f* / 

*f* (*b*)  *f* (*a*) .

**Recommended Books:**

* 1. L. Royden, Real Analysis (PHI).
  2. R. Goldberg, Methods of Real Analysis.
  3. G. De. Barra, Measure theory and Integration ( Narosa).
  4. I. K. Rana , An Introduction to Measure and Integration.
  5. W. Rudin, Principles of Mathematical Analysis.
  6. Chae, Lebesgue Integration.
  7. T. M. Apostol, Mathematical Analysis.
  8. S. M. Shah and Saxena, Real Analysis.

**DISCRETE MATHEMATICS**

Course No: **IMTH802CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To expose the students to the theory of graphs and combinatorics and to make them aware of their applications in different branches of science.

**UNIT -I**

**Graphs, traversibility and degrees**

Introduction of graphs, paths and cycles, operations on graphs, bipartite graphs and Konigs theorem, Euler graphs and Euler’s theorem, Konigsberg bridge problem, Hamiltonian graphs and Dirac’s theorem, degree sequences, Wang-Kleitman theorem, Havel-Hakimi theorem, Hakimi’s theorem, Erdos- Gallai theorem, degree sets.

**UNIT -II**

**Trees and Signed graphs**

Trees and their properties, centres in trees, binary and spanning trees, degrees in trees, Cayley’s theorem, fundamental cycles, generation of trees, Helly property, signed graphs, balanced signed graphs and characterizations.

**UNIT -III**

**Connectivity and Planarity**

Cut-sets and their properties, vertex connectivity, edge connectivity, Whitney’s theorem, Menger’s theorem (vertex and edge form), properties of a bond, block graphs, planar graphs, Kuratowski’s two graphs, embedding on a sphere, Euler’s formula, Kuratowski’s theorem, geometric dual, Whitney’s theorem on duality, regular polyhedras.

**UNIT -IV**

**Matrices and Digraphs**

Incidence matrix *A(G)*, modified incidence matrix *A*f, cycle matrix *B(G)*, fundamental cycle matrix *Bf*, cut-set matrix *C(G)*, fundamental cut set matrix *Cf*, relation between *A*f , *Bf* and *Cf* , path matrix, adjacency matrix, matrix tree theorem, types of digraphs, types of connectedness, Euler digraphs, Hamiltonian digraphs, arborescence, matrices in digraphs, Camions theorem, tournaments, characterization of score sequences, Landau’s theorem, oriented graphs and Avery’s theorem.

**A. Recommended Books:**

1. R. Balakrishnan, K. Ranganathan, A Text Book of Graph Theory, Springer-Verlag, New York.
2. B. Bollobas, Extremal Graph Theory, Academic Press.
3. F. Harary, Graph Theory, Addison-Wesley.
4. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall.
5. S. Pirzada, An Introduction to Graph Theory, Universities Press, Orient Blackswan, 2012.
6. W. T. Tutte, Graph Theory, Cambridge University Press.
7. D. B. West, Introduction to Graph Theory, Prentice Hall.

## Complex Analysis- II

Course No: **IMTH 803 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

### Unit-I

Maximum Modulus Principle, Schwarz Lemma and its generalization, Meromorphic function, Argument Principle, Rouche’s theorem with application, Inverse function Theorem, Poisson integral formula for a circle and half plane, Poisson Jenson formula, Carleman’s theorem, Hadamard three-circle theorem and the theorem of Borel and Caratheodory**.**

### Unit-II

Principle of analytic continuation, uniqueness of direct analytical continuations and uniqueness of analytic continuation along a curve. Power series method of analytic continuation, Functions with natural boundaries and related examples. Shewartz reflection principle, functions with positive real part.

### Unit-III

Space of analytic functions, Hurwitz’s theorem, Montel’s theorem, Riemann Mapping theorem, Weistrass factorization theorem, Gamma function and its properties. Riemann Zeta function, Reimann’s functional equation. Harmonic functions on a disc, Harnack’s inequality and theorem, Dirichlet’s problem, Green’s functions.

Unit IV

Canonical products, order of an entire functions, Exponential convergence, Borel theorem,

Hadamard’s factorization theorem, The Range of analytic functions, Bloch’s Theorem,

Schottky’s Theorem, The Little Picard’s Theorem, Landau’s Theorem, Great Picard Theorem (statement and applications only), Univalent function. Bieberbach’s conjecture (statement only) and the 1/4 – theorem.

**Text Books:**

1. *Complex Analysis,* L. Ahlfors, Springer.
2. *Theory of Functions,* E.C. Titchmarsh Oxford University Press

***References:***

1. *Functions of a complex variable –I*, J.B. Conway, Springer.
2. *Complex Analysis*, Richard Silverman, Dover publications.
3. *Theory of Functions of a Complex variable*, A. I. Markushevish,

**ADVANCED CALCULUS**

Course No: **IMTH 804 CR** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To extend the ideas of a function of one variable to several variables in order to solve extremal problems of analysis.

**UNIT-I**

Functions of several variables in Rn, the directional derivative, directional derivative and continuity, total derivative, matrix of a linear function, Jacobian matrix, chain rule, mean value theorem for differentiable functions.

**UNIT-II**

Sufficient conditions for differentiability and for the equality of mixed partials, Taylor’s theorem for functions from Rn and R, inverse and implicit function theorem in Rn , extremum problems for functions on Rn, Lagrange’s multiplier’s, multiple Riemann Integral and change of variable formula for multiple Riemann integrals.

**Recommended Books:**

* 1. W.Rudin, Principles of Mathematical Analysis.
  2. T.M.Apostol, Mathematical Analysis.
  3. S.M.Shah and Saxen, Real Analysis.

**Discipline Centric Electives (DCE)**

**THEORY OF NUMBERS**

Course No: **IMTH 805DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To equip the student with the properties of numbers and the relationship between different sorts of numbers in order to tackle different problems of the real number system.

**UNIT-I**

Divisibility, the division algorithm and its uniqueness, Greatest common divisor and its properties. The Euclidean algorithm, Prime numbers. Euclid’s first theorem, Fundamental Theorem of Arithmetic, Divisor of n, Radix- representation Linear Diophantine equations. Necessary and sufficient condition for solvability of linear Diophantine equations, Positive solutions.

**UNIT-II**

Sequence of primes, Euclid’s Second theorem, Infinitude of primes of the form 4n+3 and of the form 6n+5. No polynomial f(x) with integral coefficients can represent primes for all integral values of x or for all sufficiently large x. Fermat Numbers and their properties. Fermat Numbers are relatively prime. There are arbitrary large gaps in the sequence of primes. Congruences, Complete Residue System (CRS), Reduced Residue System (RRS) and their properties. Fermat and Euler’s theorems with applications.

**UNIT-III**

Euler’s ф-function, ф (mn) = ф (m) ф (n) where (m, n) =1, **(*d* )  *n*

*d m*

and

 1 

** (*m*)  *m*1  *p* 

for m>1. Wilson’s theorem and its application to the solution

*p*  

the congruence of x2\_  -1(mod p), Solutions of linear Congruence’s. The necessary and sufficient condition for the solution of a1x1+a2x2 +…+anxn  c(mod m). Chinese Remainder Theorm.Congruences of higher degree F(x)  0 (mod m), where F(x) is a Polynomials. Congruence’s with prime power, Congruences with prime modulus and related results. Lagrange’s theorem, viz , the polynomial congruence F(x)  0 (mod p) of degree n has at most n roots.

**UNIT-IV**

Factor theorem and its generalization. Polynomial congruences F(x1,x2….xn)  0 (mod p) in several variables. Equivalence of polynomials. Theorem on the number of solutions of congruences: Chevalley’s theorem, Warning’s theorem. Quadratic forms over a field of characteristic ≠ 2 Equivalence of Quadratic forms. Witt’s theorem. Representation of Field Elements. Hermite’s theorem on the minima of a positive definite quadratic form and its application to the sum of two, three and four squares.

**Recommended Books:**

* 1. W. J . Leveque, Topics in Number Theory, Vol. I and II Addition Wesley Publishing Company, INC.
  2. I. Niven and H.S Zuckerman, An introduction of the Theory of Numbers.
  3. Boevich and Shaferivich, Number Theory, I.R, Academic Press**.**

**References:**

1. T.M Apostal, Analytic Number Theory, Springer Verlag.
2. G.H Hardy and Wright, An introduction to the theory of Numbers.
3. J.P. Serre, A course in Arithmetic, GTM Vol. Springer Verlag 1973.
4. E. Landau, An Elementary Number Theory.

**OPERATION RESERACH**

Course No: **IMTH 806 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To equip the student with methods and trends for taking management decisions and networking.

**UNIT –I**

Definition of operation research, main phases of OR study, linear programming problems (LPP), applications to industrial problems –optimal product links and activity levels, convex sets and convex functions, simplex method and extreme point theorems, Big M and Two phase methods of solving LPP.

**UNIT -II**

Revised simplex method, assignment problem, Hungarian method, transportation problem, and mathematical formulation of transportation problem, methods of solving (North-West Corner rule, Vogel’s method and U.V. method), concept and applications of duality, formulation of dual problem, duality theorems (weak duality and strong duality theorems), dual simplex method, primal- dual relations, complementary slackness theorems and conditions.

**UNIT -III**

Sensitivity Analysis: changes in the coefficients of the objective function and right hand side constants of constraints, adding a new constraint and a new variable, Project management: PERT and CIM, probability of completing a project.

**UNIT -IV**

Game theory: Two person zero sum games, games with pure strategies, games with mixed strategies, Min. Max. principle, dominance rule, finding solution of

2 x 2, 2 x m, 2 x m games, equivalence between game theory and linear programming problem(LPP), simplex method for game problem.

**Recommended Books:**

1. C.W.Curchman, R.L. Ackoff and E.L.Arnoff, (1957) Introduction to Operation Research.
2. F. S Hiller and G.J. Lieberman, Introduction to Operations Research (Sixth Edition), McGraw Hill International, Industries Series, 1995.
3. G. Hadley, Linear programming problem, Narosa publishing House, 1995.
4. S.I.Gauss , Linear Programming, Wiley Eastern.
5. Kanti Swarup, P.K Gupta and M.M.Singh M. M, Operation Research; Sultan Chand & Sons.

**INTRODUCTION TO MATHEMATICAL MODELLING**

Course No: **IMTH 807 OE** Total Credits: **02**

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To enable the student to formulate mathematical models of real life problems and find their solutions.

**UNIT -I**

Introduction to mathematical modeling, types of modeling, classification of mathematical models, formulation, solution and interpretation of a model, models in population dynamics, linear growth and decay models, non-linear growth and decay models, continuous population models for single species, delay models, logistic growth model, discrete models, age structured populations, Fibonacci’s rabbits, the golden ratio, compartment models, limitations of mathematical models.

**UNIT -II**

Mathematical modeling through system of ordinary differential equations, compartment models through system of ODE’s, modeling in economics, medicine, international trade, gravitation; planetary motion; basic theory of linear difference equations with constant coefficients, mathematical models through difference equations in population dynamics, finance and genetics, modeling through graphs.

**Books Recommended:**

1. J. N. Kapur, Mathematical Modelling, New Age International Publishers.
2. Neil Gerschenfeld : The nature of Mathematical modeling, Cambridge University Press, 1999.
3. A. C. Fowler : Mathematical Models in Applied Sciences, Cambridge University Press, 1997.
4. M. R. Cullen, Linear Models in Biology, Ellis Harwood Ltd.
5. J.N. Kapur, Mathematical Model in Biology and Medicines.

**INTEGRAL EQUATIONS**

Course No. **IMTH 808 DCE** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To acquaint the student with tackling integral equations that include energy transfer, heat equation, oscillation of a string etc., that may enable them to solve different type of differential equations.

**UNIT -I**

Linear integral equations of the first and second kinds, Volterra and Fredholm integral equations, relations between differential and integral equations, solution of Volterra and Fredholm integral equations by the methods of successive substitutions and successive approximations, iterated and resolvent kernels, Neumann series, reciprocal functions, Volterra’s solutions of Fredholm equations.

**UNIT -II**

Fredholm theorems, Fredholm associated equation, solution of integral equations using Fredholm’s determinant and minor, homogeneous integral equations, integral equations with separable kernels, the Fredholm alternatives, symmetric kernels, Hilbert Schmidt theory for symmetric kernels, applications of integral equations to differential equations, initial value problem, boundary value problem, Dirac-Delta function, Green’s function approach.

**Books Recomended:**

* 1. R.P. Kanwal, Linear Integral Equations (Theory and Technique), Academic Press Birkhauser-1997.
  2. W.V. Lovitt, Linear Integral Equations, Dover Publications, Inc. New York, 1950.
  3. K.F. Riley, M.P. Hobson and S.T. Bence, Mathematical Methods for Physics and Engineering Cambridge University Press, U.K., 1997.

**References:**

1. M.D. Raisinghania, Integral Equations and Boundary Value Problems,S.C. Chand India, 2007.
2. Shanti Swarup, Integral Equations (&Boundary Value Problems), Krishna Prakashan Media (P) Ltd. Meerut, India, 2014.

**RIEMANNIAN GEOMENTRY**

Course No. **IMTH 809 DCE** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**UNIT-I**

Tensors-Order and rank of the tensors- transformation laws covariant and contra variant- tensors- Addition, subtraction and multiplication of tensor- Christoffel symbols of first and second rank and their transformation law. Tensor fields and their components, Transformation formula for components of tensors. Operations on tensors. Contraction, Covariant derivatives of tensor fields.

**UNIT-II**

Hypersurfaces of Riemannian manifolds Gauss formula, Gauss equation, Codazzi equation, Sectional Curvature for a hyper surface of a Riemannian manifolds, Gauss map, Weingartan map and Fundamental forms on hypersurface, Equations of Gauss and Codazzi, Gauss theorem egregium. Curves and geodesics in Riemannian manifold Geodesic curvature, Frenet formula.

TEXT BOOKS:

1. Y.Matsushima: Differentiable manifolds. Marcel Dekker Inc. New York, 1972.
2. W.M.Boothby: An introduction to Differentiable manifolds and Riemannian Geometry. Academic Press Inc. New York, 1975.
3. N.J.Hick: Notes in differential Geometry D.Van Nostrand Company Inc. Princeton, New Jersey, New York, London ( Affilaiated East-West Press Pvt. Ltd. new Delhi), 1998.

REFFERENCE BOOKS

1. R.L.Bishop and Grittendo: Geometry of manifolds, Acamedic Press, New York, 1964.
2. L.P.Eisenhart: Riemannian Geometry, Princeton University Press, princetion, New Jersey, 1949.
3. H.Flanders: Differential forms with applications to the Physical Science Academic Press, New York, 1963.
4. R.L.Bishop and S.J.Goldberg: Tensor analysis on manifolds, Macmillan Co-1968.
5. K.S.Amur, D.J.Shetty and C.S. Bagewadi, An introduction to differential Gemometry, Narosa Pub. New Delhi,2010.

**Generic Electives (GE)**

**COMPLEX VARIABLES**

Course No. **IMTH 810 GE** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To enable the students to understand basic concepts of complex variables as an extension of real number system.

**UNIT -I**

Review of complex numbers, De-Movier’s theorem and it’s applications, functions of a complex variable, continuity and differentiability of complex functions, analytic functions, CR equations, complex integration, Cauchy’s theorem (statement only), Cauchy’s integral formulae, Liouville’s theorem, Fundamental theorem of algebra.

**UNIT -II**

Maximum modulus principle (statement only), determination of maximum modulus of ez, sin z, cos z etc, expansion of an analytic function in a power series, Taylor’s and Laurant’s theorems (statements only), classification of singularities, zeros of analytic functions, argument principle, Rouche’s theorem and its applications.

**Books Recomended:**

* 1. W.Rudin, Complex Analysis.
  2. Alfhors, Complex Analysis.
  3. S. Ponaswamy, Foundations of Complex Analysis.
  4. Schaum series, Complex Variables.

**Open Electives (OE)**

**MATRIX ALGEBRA**

Course No. **IMTH 811 OE** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To enable the student understand the basic concepts of matrices in order to solve real life problems through solution of equations.

**UNIT -I**

Matrices, types, adjoint and inverse of a matrix, partition of a matrix, matrix polynomials, characteristic equation of a matrix, Caley Hamilton theorem, elementary transformations, rank of a matrix, determination of rank.

**UNIT - II**

Normal form with examples, solution of equations, homogenous and non- homogeneous equations, linear dependence and independence, orthogonal and unitary matrices and their determination, eigen values and eigen vectors and their determination, similarity of matrices with examples.

**Books Recommended**

* 1. Franz E. Hohn, Elementary Matrix Algebra, American Publishing company Pvt.ltd.
  2. Shanti Narayan, A Text Book of Matrices, S. Chand and company Ltd.
  3. Rajendra Bhatia , Matrix Analysis Springer.
  4. A.Aziz, N.A.Rather and B.A.Zargar, Elementary Matrix Algebra , KBD.

**Core (CR)**

**SEMESTER-IX**

**ORDINARY DIFFRENTIAL EQUATIONS**

Course No: **IMTH 901 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To enable the student to solve initial value problems pertaining to ordinary differential equations for various applications day to day life.

**UNIT -I**

First order ODE, singular solutions, p-discriminate and c-discriminate, initial value problem of first order ODE, general theory of Homogeneous and non-homogeneous linear ODE, simultaneous linear equations with constant coefficients, normal form, factorization of operators. method of variation of parameters, Picard’s theorem on the existence and uniqueness of solutions to an initial value problem.

**UNIT** -**II**

Solution in Series: (i) roots of an indicial equation, unequal and differing by a quantity not an integer. (ii) roots of an indicial equation, which are equal.

1. roots of an indicial equation differing by an integer making a coefficient infinite. (iv) roots of an indicial equation differing by an integer making a coefficient indeterminate.

Simultaneous equation

*dx* / *P*  *dy* / *Q*  *dz* / *R*

and its solutions by use of

multipliers and a second integral found by the help of first, total differential equations Pdx + Qdy +Rdz = 0, necessary and sufficient condition that an equation may be integrable, geometric interpretation of the Pdx + Qdy + Rdz

=0.

**UNIT -III**

Existence of solutions, initial value problem, Ascoli- lemma, Cauchy Piano existence theorem, uniqueness of solutions with examples, Lipchitz condition and Gronwall inequality, method of successive approximation, Picard-Lindlof

theorem, continuation of solutions, system of differential equations, dependence of solutions on initial conditions and parameters.

**UNIT -IV**

Maximal and minimal solutions of the system of ordinary differential equations, Cartheodary theorem, linear differential equations, linear homogeneous equations, linear system with constant coefficients, linear systems with periodic coefficients, fundamental matrix and its properties, non-homogeneous linear systems, variation of constant formula, Wronskian and its properties.

**Recommended Books:**

* 1. H.T.H. Piaggio, Differential Equations, CBS Publishers and Distributors, New Delhi.
  2. P.Hartmen, Ordinary Differential Equations.
  3. W.T.Reid, Ordinary Differential Equations.
  4. E.A.Coddington and N.Levinson, Theory of Ordinary Differential Equations.

1. D. Somasundaram, Ordinary Differential Equations, Narosa Publishers, New Delhi.

**Computational Mathematics with MATLAB**

Course No: **IMTH 902 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**UNIT –I**

Introduction to MATLAB Programing-Basic Programing Constructs- Arrays and vectors- Symbolic Math in MATLAB- 2D and 3D plotting.

**UNIT –II**

Polynomial- Degree of a Polynomial- Polynomial representation – Evaluating polynomials (value of Polynomial)- Plotting a Polynomial- Roots of a Polynomial:- Numeric roots- Symbolic roots- solving equations symbolically- Solving system of equations symbolically- determining Coefficients of a polynomial- factorizing a polynomial- Expanding a polynomial- Simplifying a polynomial- Mathematical operation.

**UNIT –III**

Calculus- Symbolic and Numeric integration-Indefinite and definite integrals- Symbolic vs Numerical differentiation- Numerical approximation to derivatives- Partial derivatives.

**UNIT –IV**

Linear Equations- Elementary Solution methods to solve linear equations- Matrix methods for linear Equations- Solving Higher order Equations- Solving system of equations- Differential equations- Solving ordinary differential equations- Plotting differential equations- Solution using ode solvers (ode 23, ode 45).

**FUNCTIONAL ANALYSIS-I**

Course No: **IMTH 903 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40 **Objectives:** To extend the concepts of real and complex domain to abstract spaces in order to gain insight in the real world phenomenon.

**BANACH SPACE:**

**UNIT -I**

Banach Spaces: definition and examples, subspaces, quotient spaces, continuous linear operators and their characterization, completeness of the space L( X,Y ) of bounded linear operators (and its converse), incompleteness of C[ a, b ], under the integral norm, finite dimensional Banach spaces, equivalence of norms on finite dimensional space and its consequences, dual of a normed linear space, Hahn Banach theorem (extension form) and its applications, complemented subspaces, duals of lpn, Co , lp (p≥1), C[ a, b ].

**UNIT -II**

Uniform boundedness, principle and weak boundedness, dimension of an  - dimensional Banach space, conjugate of a continuous linear operator and its properties, Banach-Steinhauss theorem, open mapping and closed graph theorems, counterexamples to Banach-Steinhauss, open mapping theorem and closed graph theorems for incomplete domain and range spaces, separable Banach spaces and the separability of some concrete Banach spaces (Co, C[ 0,1

], lp, p≥1 ), reflexive Banach Spaces, closed subspace and the dual of a reflexive Banach space, examples of reflexive and non-reflexive Banach spaces.

**UNIT -III**

**HILBERT SPACE**:

Hilbert spaces: definition and examples, Cauchy’s Schwartz inequality, parallogram law, orthonormal (o.n) systems, Bessel’s inequality and Parseval’s Identity for complete orthonormal systems, Riesz-Fischer theorem, Gram Schmidt process, o.n basis in separable Hilbert spaces.

**UNIT -IV**

Projection theorem, Riesz Representation theorem, counter example to the projection theorem and Riesz representation theorem for incomplete spaces, Hilbert property of the dual of a Hilbert space and counter examples of incomplete inner product spaces, reflexivity of Hilbert space, adjoint of a Hilbert space operator, weak convergence and Bolzano-Weirstrass property in Hilbert Spaces, normal and unitary operators, finite dimensional spectral theorem for normal operators**.**

**Recommended Books:**

* 1. B.V.Limaya, Functional Analysis.
  2. C.Goffman G. Pedrick, A First Course in Functional Analysis.
  3. L.A. Lusternick & V.J. Sobolov, Elements of Functional Analysis.
  4. J.B. Conway, A Course in Functional Analysis.

**FOURIER ANALYSIS**

Course No. **IMTH 904CR** Total Credits: **02**

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** The primary object of this course is to give conceptual knowledge of Fourier Series and its applications to heat flow and vibrating string problems.

**UNIT -I**

**Fourier Series**

Motivation and definition of Fourier series, Fourier series over the interval of length 2π, change of the interval, the complex exponential Fourier series, criteria for the convergence of Fourier series, Riemann-Lebesgue lemma, convergence at a point of continuity and at a point of discontinuity, uniform convergence and convergence in mean of the Fourier series.

**UNIT -II**

**Derivatives and Integrals of Fourier Series**

Differentiation of Fourier series, differentiation of the sine and cosine series, convergence theorems related to the derived Fourier series, integration of Fourier series, applications of Fourier series to Heat flow and Vibrating string problems.

**Books Recommended:**

* 1. E.M. Stein and R. Shakarchi, Fourier Analysis, An introduction, Princeton University Press, 2002.
  2. K. B. Howell, Principles of Fourier Analysis, Chapman & Hall/ CRC, Press, 2001.
  3. Lokenath Debnath, Wavelet Transforms and their Applications, Birkhauser, 2002.
  4. G. P. Tolstov, Fourier Series, Dover, 1972.
  5. Zygmund, Trigonometric Series (2nd Ed., Volume I & II Combined), Cambridge University Press, 1959.

**Discipline Centric Electives (DCE)**

**ADVANCED GRAPH THOERY**

Course No: **IMTH 905 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To expose the student to the various concepts of graph theory in order to model many types of relations and processes in physical, biological, social and information systems.

**Colorings**

Vertex coloring, chromatic number

**UNIT -I**

** (*G*) , bounds for

** (*G*) , Brook’s theorem,

edge coloring, Vizing’s theorem, map coloring, six color theorem, five color theorem, every graph is four colourable iff every cubic bridgeless plane map is

1. colorable, every planar graph is 4-colorable iff coloring theorem, uniquely colorable graphs

**UNIT -II**

** (*G*)  3,

Heawood map-

**Matchings**

Matchings and 1-factors, Berge’s theorem, Hall’s theorem, 1-factor theorem of Tutte, antifactor sets, f-factor theorem, f-factor theorem implies1-factor theorem, Erdos- Gallai theorem follows from f-factor theorem, degree factors, *k*-

factor theorem, factorization of *Kn* .

**UNIT -III**

**Edge graphs and eccentricity sequences**

Edge graphs, Whitney’s theorem on edge graphs, Beineke’s theorem, edge graphs of trees, edge graphs and traversibility, total graphs, eccentricity sequences and sets, Lesniak theorem for trees, construction of trees, neighbourhoods, Lesniak theorem graphs.

**UNIT -IV**

**Groups in graphs and graph spectra**

Automorphism groups of graphs, graph with a given group, Frucht’s theorem, Cayley digraph, spectrum of a graph, spectrum of some graphs-regular graph, compliment of a graph, edge graph, complete graph, complete bipartite, cycle and path, Laplacian spectrum, energy of a graph, Laplacian energy.

**Recommended Books:**

* 1. R. Balakrishnan, K. Ranganathan, A Text Book of Graph Theory, Springer-Verlag, New York
  2. B. Bollobas, Extremal Graph Theory, Academic Press.
  3. F. Harary, Graph Theory, Addison-Wesley.
  4. Narsingh Deo, Graph Theory with Applications to Engineering and Computer Science, Prentice Hall
  5. S. Pirzada, An Introduction to Graph Theory, Universities Press, Orient Blackswan, 2012
  6. W. T. Tutte, Graph Theory, Cambridge University Press.
  7. D. B. West, Introduction to Graph Theory, Prentice Hall

**ABSTRACT MEASURE THEORY**

Course No: **IMTH 906 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To extend the concept of measure to abstract spaces for various measures in order to obtain corresponding analogs of various results of Lebesgue measure.

**CREDIT-I**

Semi-ring, ring, algebra and ** - algebra of sets, measures on semi-rings, outer measure associated with a set function and basic properties, measurable sets associated with an outer measure as a ** - algebra , outer

measure induced by a measure, non measurable sets.

**CREDIT-II**

Finite and 𝜎- Finite measure spaces, Measurable sets of finite measure space, Improper Riemann integral as a Lebesgue integral, calculation of some improper Riemann integrable functions, Approximation of integrable functions, Riemann Lebesgue lemma.

**CREDIT-III**

Product measures and product 𝜎- algebra, measurable rectangles, monotone class and elementary sets, expressing a double integral as an iterated integral, examples of non-integrable functions whose iterated integrals exist (and are equal), Integration on product spaces, Fubini theorem.

**CREDIT-IV**

For f Є L1 [ a, b ], F/= f a.e. on [ a, b ]. If f is absolutely continuous on ( a, b) with f(x)=0 a.e, then f = constant. Characterization of an absolutely continuous function as an indefinite Lebesgue integral. Non-Lebesgue integrability of f where f (x) = x2sin(1/ x2) , f (0) =0 on [ 0, 1 ]. Fundamental theorem of calculus for the Lebesgue integral. A brief introduction to Lp spaces. Holder’s and Minkowki’s inequalities.

**Recommended Books:**

1.C.D.Aliprantis and O.Burkinshaw, Principles of Real Analysis 2.Goldberg , R. : Methods of Real Analysis

3.T.M.Apostol : Mathematical Analysis

**Suggested Readings:**

1. Royden, L: Real Analysis (PHI)
2. Chae, S.B. Lebesgue Integration(Springer Verlag).

3. Rudin, W. Principles of Mathematicals Analysis(McGraw Hill).

4. Barra ,De. G. : Measure theory and Integration ( Narosa)

5. Rana ,I.K. : An Introduction to Measure and Integration, Narosa

Publications.

**MATHEMATICAL BIOLOGY**

Course No: **IMTH 907 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To apply mathematical and statistical techniques including ODES/PDES, numerical methods, hypothesis testing, regression, matrices etc. in the context of biological systems.

**UNIT -I**

Diffusion in biology: Fick’s law of diffusion, Fick’s perfusion law, membrane transport, diffusion through a slab, convective transport, trancapillary exchange, heat transport in biological tissues, oxygen transport through red cells, gas exchange in lungs, the ideal gas law and solubility of gases, the equation of gas transport in one Alveolus.

**UNIT -II**

Biofluid mechanics: introduction, various types of fluid flows, viscosity, basic equation of fluid, mechanics, continuity equation, equation of motion, the circulatory system, systemic and pulmonary circulation, the circulation in heart, blood composition, arteries and arterioles, models in blood flow, Poiseulle’s flow and its applications, the pulse wave.

**UNIT -III**

Tracers in physiological systems: compartment systems, the one compartment system, discrete and continuous transfers, ecomatrix, the continuous infusion, the two compartment system, bath-tub models, three-compartment system, the leaky compartment and the closed systems, elementary pharmacokinetics, parameter estimation in two compartment models, basic introduction to n- compartment systems.

**UNIT -IV**

Biochemical reactions and population genetics: the law of mass action, enzyme kinetics, Michael’s- Menten theory, competitive inhibition, Allosteric inhibition, enzyme-substrate-inhibitor system, cooperative properties of enzymes, the cooperative dimer, haemoglobin. haploid and diploid genetics, spread of favourite allele, mutation-selection balance, heterosis, frequency dependent selection.

**Books Recommended**

* 1. J.D. Murray, Mathematical Biology, CRC Press
  2. S.I. Rubinow, Introduction to Mathematical Biology, John Wiley and Sons.
  3. Guyton and Hall, Medical Physiology.
  4. S.C. Hoppersteadt and C.S. Peskin, Mathematics in Medicine and Life Sciences, Springer-Verlag
  5. J.R. Chesnov, Lecture notes in Mathematical Biology, Hong Kong Press
  6. J. N. Kapur, Mathematical methods in Biology and Medicine, New Age Publishers
  7. D. Ingram and R.F. Bloch, Mathematical methods in Medicine, John Wiley and Sons.

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|  | **WAVELET THEORY** |  |
| Course No: **IMTH 908 DCE** |  | Total Credits: **04** |
| Examination: |  | Total Marks: 100 |
| (a). Assessment |  | Max. Marks: 20 |
| (b). Theory |  | Max. Marks: 80 |
| Time Duration: 2 ½ hrs |  | Min.Pass Marks: 40 |

**Objectives:** To study powerful wavelet basic functions and find efficient methods for their competitions in order to study signal processing.

**UNIT -I**

**Time Frequency Analysis and Wavelet Transforms**

Gabor transforms, basic properties of Gabor transforms, continuous and discrete wavelet transforms with examples, basic properties of wavelet transforms, examples of Haar wavelet, Mexican hat wavelet and their Fourier transforms, dyadic orthonormal wavelet bases for 𝐿2(ℝ).

**UNIT -II**

**Multiresolution Analysis and Construction of Wavelets**

Definition and examples of multiresolution analysis (MRA), properties of scaling functions and orthonormal wavelet bases, construction of orthonormal wavelets with special reference to Haar wavelet, Franklin wavelet and Battle- Lemarie wavelet, Spline wavelets, construction of compactly supported wavelets, Daubechie’s wavelets and algorithms.

**UNIT -III**

**Other Wavelet Constructions and Characterizations**

Introduction to basic equations, some applications of basic equations, characterization of MRA wavelets and scaling functions, construction of biorthogonal wavelets, wavelet packets, definition and examples of wavelets in higher dimensions.

**UNIT -IV**

**Further Extensions of Multiresolution Analysis**

Periodic multiresolution analysis and the construction of periodic wavelets, multiresolution analysis associated with integer dilation factor (M-band wavelets), harmonic wavelets, properties of harmonic scaling functions.

**Recommended Books:**

1. L. Debnath, Wavelet Transforms and their Applications, Birkhauser, 2002.
2. I. Daubechies, Ten Lectures on Wavelets, CBS-NSF Regional Conferences in Applied Mathematics, 61, SIAM, Philadelphia, PA, 1992.
3. K. Ahmad and F. A. Shah, Introduction to Wavelets with Applications, Real World Education Publishers, New Delhi, 2013.

**References:**

1. C. K. Chui, An Introduction to Wavelets, Academic Press, New York, 1992.
2. M. Pinsky, Introduction to Fourier Analysis and Wavelets, Brooks/Cole, 2002.
3. E. Hernandez and G. Weiss, A First Course on Wavelets, CRC Press,New York (1996).

**Generic Electives (GE)**

**ARTIFICIAL INTELLIGENCE**

Course No. **IMTH 909 GE** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Unit I:**

Introduction to artificial intelligence, First Order Logic, Inference in First Order Logic, Prepositional versus First Order Logic, Expert Systems Forward chaining, Backward chaining, conflict Resolution, Knowledge representation, Uncertainty theory.

**Unit II:**

Search Algorithms, Heuristic Search, Genetic Algorithms, Cross over, Mutation, Fuzzy Logic, Fuzzification , Fuzzy Sets, Hedges, Max-product inferencing, Multiple premise inference, Multiple rule inference, Defuzzification.

**TEXTBOOK:**

1. Artificial intelligence by Negnevitsky, Addison Wesley Publication.

**References:**

1. Patterson, “ Introduction to Artificial Intelligence and expert systems”, PearsonEducation.
2. Elaine Rich and Kevin Knight, “ Artificial Intelligence”, Tata Mcgraw-Hill, 2003.
3. **Luger , G.F, “**Artificial Intelligence, structures and stratigies for complex problem solving”, PearsonEducation/Prentise Hall of india -2002.

**Open Electives (OE)**

**MATHEMATICAL MODELLING**

Course No. **IMTH 910 OE** Total Credits: **02**

Examination: Total Marks: 50

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To provide the students a system using mathematical concepts and language for developing a mathematical model for certain day to day problems.

**UNIT -I**

Introduction to mathematical modeling, types of modeling, classification of mathematical models, formulation, solution and interpretation of a model, linear growth and decay models, non-linear growth and decay models, continuous population models for single species, logistic growth model, discrete models, age structured populations, delay models, Fibonacci’s rabbits, the golden ratio, compartment models, limitations of mathematical models.

**UNIT -II**

Mathematical models in ecology and epidemiology: models for interacting populations, types of interactions, Lotka-Voltera system and stability analysis of the interactions like prey-predator, competition and symbiosis, infectious disease modelling, simple and general epidemic models viz SI, SIS, SIR epidemic disease models, vaccination, the SIR endemic disease model.

**Books Recommended**

* 1. J. N. Kapur, Mathematical Modelling, New Age International Publishers.
  2. J.D. Murray Mathematical Biology (An Introduction, Vol. I and II), Springer Verlag.
  3. J.N. Kapur, Mathematical Model in Biology and Medicines.
  4. S. I. Rubinow, Introduction to Mathematical Biology, John Wiley and Sons, 1975.
  5. M. R. Cullen, Linear Models in Biology, Ellis Harwood Ltd.
  6. Jaffrey R. Chasnov, Mathematical Biology, Hong Kong Press.

**Core (CR)**

**SEMESTER-X**

**PARTIAL DIFFRENTIAL EQUATIONS**

Course No: **IMTH 1001 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To familiarize the students with the fundamental concepts of PDE’s and their solutions in the context of Laplace, Heat and Wave equations.

**UNIT -I**

Introduction to partial differential equations, partial differential equations of first order, linear and non-linear partial differential equations, Lagrange’s method for the solution of linear partial differential equations, Charpits method and Jacobi methods for the solution of non-linear partial differential equations, initial-value problems for quasi-linear first-order equations, Cauchy’s method of characteristics.

**UNIT -II**

Origin of second order partial differential equations, linear partial differential equations with constant coefficients, methods for solution of second order partial differential equations, classification of second order partial differential equations, canonical forms, adjoint operators, Riemann’s method, Monge’s method for the solution of non-linear partial differential equations.

**UNIT -III**

Derivation of Laplace and heat equations, boundary value problems, Drichlet’s and Neumann problems for a circle and sphere; solutions by separation of variables method, cylindrical coordinates and spherical polar coordinate system, maximum-minimum principle, uniqueness theorem, Sturm-Liouville theory.

**UNIT -IV**

Derivation of wave equation, D’ Alembert’s solution of one dimensional wave equation, separation of variables method, periodic solutions; method of eigen functions, Duhamel’s principle for wave equation, Laplace and Fourier transforms and their applications to partial differential equations, Green function method and its applications.

**Recommended Books:**

* 1. Robert C. McOwen, Partial Differential Equations-Methods and Applications, Pearson Education, Delhi, 2004.
  2. L. C. Evans, Partial Differential Equations, GTM, AMS, 1998
  3. Diran Basmadjian, The Art of Modelling in Science and Engineering, Chapman & Hall/CRC, 1999.
  4. E. DiBenedetto, Partial Differential Equations, Birkhauser, Boston, 1995.
  5. F. John, Partial Differential Equations, 3rd ed., Narosa Publ. Co., New Delhi,1979.
  6. E. Zauderer, Partial Differential Equations of Applied Mathematics, 2nd ed., John Wiley and Sons, New York, 1989

**DIFFRENTIAL GEOMETRY**

Course No: **IMTH 1002 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To inculcate the students to study the geometric properties of curves, surfaces and their higher-dimensional analogs using the methods of calculus.

**UNIT -I**

Curves: differentiable curves, regular point, parameterization of curves, arc- length, arc-length is independent of parameterization, unit speed curves, plane curves, curvature of plane curves, osculating circle, centre of curvature. computation of curvature of plane curves, directed curvature, examples, straight line, circle, ellipse, tractrix, evolutes and involutes, space curves, tangent vector, unit normal vector and unit binormal vector to a space curve, curvature and torsion of a space curve, the Frenet-Serret theorem, first fundamental theorem of space curves, intrinsic equation of a curve, computation of curvature and torsion, characterization of helices and curves on sphere in terms of their curvature and torsion, evolutes and involutes of space curves**.**

**UNIT -II**

Surfaces: regular surfaces with examples, coordinate charts or curvilinear coordinates, change of coordinates, tangent plane at a regular point, normal to the surface, orientable surface, differentiable mapping between regular surfaces and their differential, fundamental form or a metric of a surface, line element, invariance of a line element under change of coordinates, angle between two curves, condition of orthogonality of coordinate curves, area of bounded region, invariance of area under change of coordinates.

**UNIT -III**

Curvature of a Surface: normal curvature, Euler’s work on principal curvature, qualitative behavior of a surface near a point with prescribed principal curvatures, the Gauss map and its differential, the differential of Gauss is self- adjoint, second fundamental form, normal curvature in terms of second fundamental form. Meunier theorem, Gaussian curvature, Weingarten equation, Gaussian curvature K(p)= (eg-f2)/EG-F2, surface of revolution,

surfaces with constant positive or negative Gaussian curvature, Gaussian curvature in terms of area, line of curvature, Rodrigue’s formula for line of curvature, equivalence of surfaces, isometry between surfaces, local isometry, and characterization of local isometry.

**UNIT -IV**

Christoffel symbols, expressing Christoffel symbols in terms of metric coefficients and their derivative, Theorema egrerium (Gaussian curvature is intrinsic), isometric surfaces have same Gaussian curvatures at corresponding points, Gauss equations and Manardi Codazzi equations for surfaces, fundamental theorem for regular surface. (Statement only).

Geodesics: geodesic curvature, geodesic curvature is intrinsic, equations of geodesic, geodesic on sphere and pseudo sphere, geodesic as distance minimizing curves. Gauss-Bonnet theorem (statement only), geodesic triangle on sphere, implication of Gauss-Bonnet theorem for geodesic triangle.

**Recommended Books:**

1. John Mc Cleary, Geometry from a differentiable Viewpoint. (Cambridge Univ. Press)**.**
2. W. Klingenberg, A course in Differential Geometry (Spring Verlag).
3. C. E. Weatherburn, Differential Geometry of Three dimensions.
4. T. Willmore, An Introduction to Differential Geometry.
5. J. M. Lee, Riemannian Manifolds, An Introduction to Curvature.

**ADVANCED ABSTRACT ALGEBRA-II**

Course No: **IMTH 1003 CR** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To expose the students to Galios theory in problem solving context and to apply the group theoretic information to deduce results about fields and polynomials.

**UNIT -I**

Relation and ordering, partially ordered sets, lattices, properties of lattices, lattices as algebraic systems, sub-lattices, direct product and homomorphism, modular lattices, complete lattices, bounds of lattices, distributive Lattice, complemented lattices.

**UNIT -II**

Modules, sub-modules, quotient modules, homomorphism and isomorphism theorem, cyclic modules, simple modules, semi-simple modules, Schuer's lemma, free modules, ascending chain condition and maximum condition, and their equivalence, descending chain condition and minimum condition and their equivalence, direct sums of modules, finitely generated modules.

**UNIT -III**

Fields: Prime fields and their structure, extensions of fields, algebraic numbers and algebraic extensions of a field, roots of polynomials, remainder and factor theorems, splitting field of a polynomial, existence and uniqueness of splitting fields of polynomials , simple extension of a field.

**UNIT -IV**

Separable and in-separable extensions, the primitive element theorem, finite fields, perfect fields, the elements of Galois theory, automorphisms of fields, normal extensions, fundamental theorem of Galois theory, construction with straight edge and compass, Rn is a field iff n = 1, 2.

**Recommended Books:**

* 1. I. N. Heristein, Topics in Algebra.
  2. K. S. Miller, Elements of Modern Abstract Algera.
  3. Surjeet Singh and Qazi Zameer-ud-din, Modern Algebra, Vikas Publishers Pvt. Limited.

**LINEAR ALGEBRA**

Course No: **IMTH 1004 CR** Total Credits: **02**

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min.Pass Marks: 20

**Objectives:** To inculcate the students to study linear functions and their representations through matrices and vector spaces.

**UNIT -I**

Linear transformation, algebra of linear transformations, linear operators, invertible linear transformations, matrix representation of a Linear transformation, linear functionals, dual spaces, dual basis, anhilators, eigen values and eigen-vectors of linear transformation, diagonalization, similarity of linear transformation.

**UNIT -II**

Canonical forms: triangular form, invariance, invariant direct sum decomposition, primary decomposition, nilpotent operators, Jordon canonical form, cyclic subspaces, rational canonical form, quotient spaces, bilinear forms, alternating bilinear forms, symmetric bilinear forms, quadratic forms.

**Books Recommended:**

* 1. Robort A. Beezer, A first course in linear algebra.
  2. John B. Fraleigh and Raymond, Linear Algebra.
  3. A. K. Sharma, Linear Algebra.
  4. Vivek Sahai and Vikas Bist, Linear Algebra.

**Discipline Centric Electives (DCE)**

**ANALYTIC THEORY OF POLYNOMIALS**

Course No: **IMTH 1005 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To expose to the study of polynomials, their extremal problems, zeros, critical points and their location.

**UNIT -I**

Introduction, the fundamental theorem of algebra (revisited), symmetric polynomials, the continuity theorem, orthogonal polynomials, general properties, the classical orthogonal polynomials, tools from matrix analysis.

**UNIT -II**

Critical points in terms of zeros, fundamental results and critical points, convex hulls and Gauss-Lucas theorem, some applications of Gauss-Lucas theorem, extensions of Gauss-Lucas theorem, average distance from a line or a point, real polynomials and Jenson’s theorem, extensions of Jenson’s theorem.

**UNIT -III**

Derivative estimates on the unit interval, inequalities of S. Bernstein and

A. Markov, extensions of higher order derivatives, two other extensions, dependence of the bounds on the zeros, some special classes, Bernstein Theorem on unit disk and its generalization, Lp analog of Bernstein’s inequality.

**UNIT -IV**

Coefficient estimates, polynomials on the unit circles, coefficients of real trigonometric polynomials, polynomials on the unit interval.

(Scope of above syllabus as given in the book “Analytic Theory of Polynomials” by Rahman and Schmeisser)

**Recommended Books:**

1. Q. I. Rahman and G.Schmeisser, Analytic Theory of Polynomials.
2. Morris Marden, Geometry of Polynomials.
3. G. V. Milovanovic, D.S.Mitrinovic and Th. M. Rassias, Topics in Polynomials, Extremal Properties, Problems, Inequalities, Zeroes.
4. G. Polya and G. Szego, Problems and Theorems in Analysis ( Springer Verlag New York Heidelberg Berlin).

**MATHEMATICAL STATISTICS**

Course No: **IMTH 1006 DCE** Total Credits: **04**

Examination: Total Marks: 100

(a). Assessment Max. Marks: 20

1. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Unit-I**

Characteristic function, Properties of Characteristic function, Necessary and sufficient condition for a function (*t*)to be a characteristic function, inversion theorem, uniqueness theorem of characteristics function, continuity theorem of characteristic function, Chebychev’s inequality and its applications, Weak law of large numbers, Khinchins Theorem for weak law of large numbers, Strong law of large numbers.

**Unit-II**

Central Limit Theorem and its applications, De-Moivre’s Laplace Theorem, Lindberg Levy Theorem, Liapounoff’s Central Limit Theorem, Cramer’s Theorem.

**Unit-III**

Order statistics: Definition and Properties, Cumulative Distribution Function of a Single order Statistics, Probability Density Function of Single Order Statistics, Joint and Marginal PDF of Order statistics, Discrete Order Statistics and their Joint p. m. f.

**Unit-IV**

Linear Models, Gauss-Markov Setup, Model Classification, Normal Equations and Least Square Estimates, Variance and Co-variance of least square estimates, estimation of error variance, estimation with correlated observations.

**Text books:**

* Rao, R. C: Linear Statistical Inferences and Its Applications, Wiley eastern.
* Rohatogi, V. K: An Introduction to Probability Theory and Mathematical Statistics, Wiley eastern.
* Basu, A. K: Probability and Measure Theory, Narosa publication.
* Kapoor, V. K: Fundamentals of Mathematical Statistics, S. Chand publications.

**References:**

* Searle, S. R: Linear Models, Wiley eastern.
* Pitman, J: Probability, Narosa publications.
* Draper, N and Smith, H: Linear Models in Statistics, Wiley Series in Probability and Statistics.
* Hogg and Craig: An introduction to Mathematical Statistics.

**FUNCTIONAL ANALYSIS-II**

Course No: **IMTH 1007 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To enable the student to understand the properties of Banach spaces in terms of bounded linear operators, separability and reflexivity of such spaces.

**UNIT -I**

Relationship between analytic and geometric forms of Hahn-Banach theorem, applications of Hahn-Banach theorem, Banach limits, Markov-Kakutani theorem for a commuting family of maps, complemented subspaces of Banach spaces, complentability of dual of a Banach space in its bidual,

uncomplementability of co in

*l* *.*

**UNIT -II**

Dual of subspaces, quotient spaces of a normed linear space, weak and weak\* topologies on a Banach space, Goldstine’s theorem, Banach Alaoglu theorem and its simple consequences, Banch’s closed range theorem, injective and surjective bounded linear mappings between Banach spaces.

**UNIT -III**

*l* and C[0,1] as universal separable Banach spaces, *l*1

as quotient universal

separable Banach spaces, Reflexivity of Banach spaces and weak compactness, Completeness of Lp[a,b], extreme points, Krein-Milman theorem and its simple consequences.

Dual of

**UNIT -IV**

*l* , C(X) and Lp spaces. Mazur-Ulam theorem on isometries between

real normed spaces, Muntz theoremin C[a,b].

**Recommended Books:**

* 1. J. B. Conway, A First Course in Functional Analysis (Springer Verlag).
  2. R. E. Megginson, An Introduction to Banach Space theory (Springer Verlag, GTM, Vol. 183)
  3. Lawrence Bagget, Functional Analysis, A Primer (Chapman and Hall, 1991).

**References:**

1. B. Ballobas, Linear Analysis (Camb. Univ.Pres).
2. B. Beauzamy, Introduction to Banach Spaces and their geometry( North Holland ).
3. Walter Rudin, Functional Analysis (Tata McGrawHill).

**NON-LINEAR ANALYSIS**

Course No: **IMTH 1008DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To inculcate the students to study various methods to solve problems involving the homogeneous and non-homogeneous operators.

**UNIT -I**

Convex Sets, best approximation properties, topological properties, separation, nonexpansive operators, projectors onto convex sets, fixed points of nonexpansive operators, averaged nonexpansive operators, Fejer monotone sequences, convex cones, generalized interiors, polar and dual cones, tangent and normal cones, convex functions, variants, between linearity and convexity, uniform and strong convexity, quasiconvexity

**UNIT -II**

Gateaux Derivative, Frechet Derivative, lower semicontinuous convex functions, subdifferential of convex functions, directional derivatives, characterization of convexity and strict convexity, directional derivatives and subgradients, Gateaux and Frechet differentiability, differentiability and continuity

**UNIT -III**

Monotone operators, strong notions of monotonicity such as para, cyclic, strict, uniform and strong monotonicity, maximal monotone operator and their properties, bivariate functions and maximal monotonicity, Debrunner-Flor theorem, Minty theorem, Rockfeller’s cyclic monotonicity theorem, monotone operators on *R*.

**UNIT -III**

Reisz-Representation theorem, projection mappings and their properties, characterization of projection onto convex sets and their geometrical interpretation,

Billinear forms and its applications, Lax-Milgram lemma, minimization of functionals, variational inequalities, relationship between abstract minimization problems and variational inequalities, Lions Stampacchia theorem for existence of solution of variational inequality.

**Recommended Books:**

* 1. H. H. Bauschke and P. L. Combettes, Convex Analysis and Monotone Operator Theory in Hilbert Spaces, Springer New York, 2011.
  2. D. Kinderlehrer and G. Stampacchia, An Introduction to Variational Inequalities and Their Applications, Academic Press, New York, 1980.
  3. A. H. Siddiqi, K. Ahmed and Manchanda, P. Introduction to Functional Analysis with Applications, Anamaya Publishers, New Delhi-2006.

**References:**

1. I. Ekland and R. Temam, Convex Analysis and Variational Problems, W.Takahashi, Nonlinear Functional Analysis, North-Holland Publishing Company-Ammsterdam, 1976.
2. M. C. Joshi and R. K. Bose, Nonlinear Functional Analysis and its Applications, Willey Eastern Limited, 1985.

**ADVANCED TOPICS IN TOPOLOGY AND MODERN ANALYSIS**

Course No: **IMTH 1009 DCE** Total Credits: **04**

Examination: Total Marks: 100

1. Assessment Max. Marks: 20
2. Theory Max. Marks: 80

Time Duration: 2 ½ hrs Min.Pass Marks: 40

**Objectives:** To provide the students an integrated development of modern analysis and topology through the integrating vehicle of uniforms spaces.

**UNIT -I**

Uniform spaces, definition and examples, uniform topology, metrizability complete regularity of uniform spaces, pre-compactness and compactness in uniform spaces, uniform continuity.

**UNIT II**

Uniform continuity, uniform continuous maps on compact spaces Cauchy convergence and completeness in uniform spaces, initial uniformity, simple applications to function spaces, Arzela- Ascoli theorem**.**

**UNIT -III**

Abstract harmonic analysis, definition of a topological group and its basic properties. subgroups and quotient groups, product groups and projective limits, properties of topological groups involving connectedness, invariant metrics and Kakutani theorem, structure theory for compact and locally compact, Abelian groups.

**UNIT -IV**

Some special theory for compact and locally compact Abelian groups, Haar integral and Haar measure, invariant means defined for all bounded functions, convolution of functions and measures, elements of representation theory, unitary representations of locally compact groups.

**Recommended Books:**

* 1. I. M. James, Uniform Spaces, Springer Verlag.
  2. K. D. Joshi, Introduction to General Topology.
  3. K. Berberian, Lectures on Operator Theory and Functional Analysis, Springer Verlag.
  4. G. B. Folland, Real Analysis, John Wiley.

**References:**

1. G. Murdeshwar, General Topology.
2. E. Hewitt & K.A Ross, Abstract Harmonic Analysis-I, Springer Verlag.

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|  | **PROJECT** |  |
| Course No: **IMTH 1010 DCE** |  | Total Credits: **04** |
| Examination: |  | Total Marks: 100 |
| (a). Assessment |  | Max. Marks: 20 |
| (b). Theory |  | Max. Marks: 80 |
| Time Duration: 2 ½ hrs |  | Min.Pass Marks: 40 |

**Objectives:** To develop the skill of writing mathematical topics and presentations of proofs of fundamental results pertaining to the subject

The student opting for project will have to work on the research problem in any one of the following areas:

1. **Complex Analysis**
2. **Functional Analysis**
3. **Graph Theory and Algebra**
4. **Mathematical Biology**
5. **Mathematical Statistics**

The student will be put under the guidance of faculty member of the respective areas. At the end the student will have to submit dissertation. The dissertation will carry 80 marks following which there will be a viva-voce examination carrying 20 marks.

**Open Electives (OE)**

**DISCRETE MATHEMATICS**

Course No: **IMTH 1011 OE** Total Credits: **02**

1. Assessment Max. Marks: 10
2. Theory Max. Marks: 40

Time Duration: 1 ¼ hrs Min. Pass Marks: 20

**Objectives:** To introduce the student to various concepts of Boolean Algebra and Lattices to be applied in day to day problems related to networking structure, transportation etc.

**CREDIT-I**

Lattices: Set operations, product sets, equivalence relations, relation and ordering, partially ordered sets, chain or completely ordered sets, lattices properties, lattices and algebraic systems, sub-lattices, direct product and homomorphism, modular lattices, complete lattices, distributive lattices, complemented lattices.

**CREDIT-I**

Boolean Algebra: Introduction, binary operations, algebraic structure, Boolean algebra, general properties of Boolean algebra, Boolean expressions, principle of Duality, Boolean algebra as a lattice, sub-Boolean algebra, direct product and homomorphism, representation theorem.

**Recommended Books:**

* 1. Discrete Mathematics, Schaum’s Outlines, Ind. Edition Tata McGraw-Hill Publishing Company Ltd. New Delhi.
  2. A Text Book of Discrete Mathematics, Harish Mittal, Vinay K.Goyal, Deepak K. Goyal, I. K. Int. Publishing House Pvt. Ltd (2010).
  3. Discrete Mathematical Structures, Kolman, Busby, Pross, Sixth Edition, PHI Laming Pvt. Ltd. (2010).
  4. Discrete Mathematics, Richard Johnsonbaugh, sixth edition, Pearson Prentice Hall (2007).