SYLLABUS

FOR

M.SC. IN MATHEMATICS

Under Choice Based Credit System
(CBCS)

Effective from the academic session 2016-2017

KAZI NAZRUL UNIVERSITY

ASANSOL-713 340

WEST BENGAL

Brief History of the Department:

This Department was established in 2013. This is the first Science Department of the Kazi Nazrul University. Currently the Department runs two-year (four semesters) Post Graduate Programme (M.Sc.) in Mathematics under Choice Based Credit System (CBCS). A wide variety of optional papers from the fields of Mathematics and applications are provided in the Post Graduate programme. Ph.D. programme has been started from the year 2017. M.Phil. Programme will be introduced soon.

Vision of the Department:

(i) To be a centre of excellence in education in Mathematics and research and to produce true Mathematicians.
(ii) To be a hub of knowledge creation in Mathematics that prioritises the frontier areas of national and global importance.
(iii) To contribute the development of the nation.

Mission of the Department:

(i) To provide an environment where students can learn and become competent users of Mathematics and Mathematical Applications. Moreover, the Department wants to contribute to the development of students as Mathematical thinkers, enabling them to become lifelong learners, to continue to grow in their chosen professions, and to function as productive citizens.

(ii) To provide our students a foundation for critical thinking by developing skills in logic and problem solving.

(iii) To offer our students academic challenges along with support to help them succeed. We encourage them to develop problem-solving abilities which transcend the confines of the field of Mathematics.

Programme/ Course Offered:

Name of the Course	Duration	Year from which the Course Started	Total Intake Capacity
M.Sc.	2- Year (4- Semester)	2013	50
Ph. D	Minimum 3 years	2017	20

Detailed Syllabus

SEMESTER-I

MSCMATHC101: REAL ANALYSIS

- ✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**
- ✧ **Credit: 4** ✧**L - T –P : 4 - 0 - 0**

Objectives:

- To familiarize with Functions of bounded variations, measure theory, Lebesgue integral etc.
- To understand the relation between Function of bounded variation and absolutely continuous functions, outer measure and general measure, Lebesgue integral and Riemann integral etc.
- To explain the situation where the above is applied in other branch of mathematics and higher studies.
- To extend the concept of outer measure in an abstract space and integration with respect to a measure.

Syllabus Contents

Bounded Variation: Functions of Bounded variation and their properties, Differentiation of a function of bounded variation, Absolutely continuous function, Representation of an absolutely continuous function by an integral.

Theory of Measure: Semirings and rings of sets, σ-ring and σ-algebra, Ring and σ-ring generated by a class of sets, Monotone class of sets, Monotone class generated by a ring, Borel sets, Measures on semirings and their properties, outer measure and Measurable sets, Caratheodory Extension: Outer measure generated by a measure, Lebesgue measure on R^n, Measure Space, Finite and σ-finite measure spaces, Measurable functions, Sequence of measurable functions, Egorov's theorem, Convergence in Measure.

Lebesgue Integral: Simple and Step functions, Lebesgue integral of step functions, Upper functions, Lebsegue integral of upper functions, Lebesgue integrable functions, Fatou's Lemma, Dominated Convegence theorem, Monotone convergence theorem, Riemann integral as a Lebesgue integral, Lebesgue-Vitali Theorem, Application of the Lebesgue Integral.

Outcomes:

After successful completion of the course the student would

- be able to verify whether a given subset of **R** or a real valued function is a function of bounded variation, absolutely continuous, measurable, Lebesgue integrable etc.
- be able to understand the requirement and the concept of the Bounded variation, measurable sets, measurable function, Lebesgue integral along its properties.
- be able to demonstrate understanding of the statement and proofs of the different theorems and their applications.

References:

1. Royden, H.L., Real Analysis, Pearson
2. Aliprantis, C.D., Burkinshaw, O., Principles of Real Analysis, , Harcourt Asia Pvt Ltd.
3. Halmos, P.R., Measure Theory , Van Nostrand, New York, 1950.
4. Rudin, W., Real and Complex Analysis, McGraw Hill Book Co., 1966.
5. Kolmogorov, A.N., Fomin, S.V., Measures, Lebesgue Integrals and Hilbert Space, Academic Press, New York and London, 1961.

MSCMATHC102: COMPLEX ANALYSIS

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 4** ✧**L - T –P : 4 - 0 - 0**

Objective:

- To enable the learners to learn and grasp in depth the complex analysis.
- Have the knowledge of several important theorems with their proofs, deductions and applications through problems.
- To understand the concepts of stereographic projection, different types of complex integrations, meromorphic functions, analytic continuation, etc.

Syllabus Contents

Complex numbers: Complex plane, Extended plane and its spherical representation, Stereographic Projection. Limit, Continuity and Differentiability of Complex functions, Analytic functions, Harmonic functions.

Bilinear transformation, Conformal mappings, Mapping properties of some important functions.

Complex integration: Complex integral (Over piecewise C^1 curves), Index of a closed curve, Contour, Index of a contour, Cauchy-Goursat theorem, Cauchy’s integral theorem and integral formula, Cauchy’s inequality, Power series representation of analytic functions, Morera’s theorem, Liouville’s theorem, Fundamental theorem of algebra, Zeros of analytic functions, Uniqueness theorem, Maximum modulus principle and its applications, Conformal mappings, Schwarz’s lemma and its consequences.
Singularities: Definitions and classification of singularities of complex functions, Isolated singularities, Open mapping theorem, Laurent series, Casorati-Weierstrass theorem, Poles, Residues, Residue theorem and its application to contour integrals, Meromorphic functions, Argument principle, Rouche’s theorem and its applications.
Analytic continuation: Schwarz reflection principle, Analytic continuation along a path.

Outcomes:

- Use the residue theorem to compute several kinds of real integrals.
- Determine whether a sequence of analytic functions converges uniformly on compact sets.
- Express some functions as infinite series or products.
- After learning these, the students can easily learn the advanced complex analysis after which they

will be able to do research works.

References:

1. Conway, J. B., Functions of one complex variables, Second edition, Narosa Pub.
2. Sarason, D., Complex function theory, Hindustan book agency, Delhi, 1994.
3. Ahlfors, L.V., Complex analysis, McGraw Hill, 1979.
4. Ponnusamy, S., Foundations of complex analysis, Narosa Pub.
5. Rudin, W., Real and complex analysis, Mc Graw Hill, 1966.
6. Hille, E., Analytic function theory, Gonn and Co. 1959.

MSCMATHC103: ABSTRACT ALGEBRA

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objectives:

- To introduce and discuss in details some topics of Group theory such as class equations of a finite group, Sylow's theorems, simple groups.
- To acquire knowledge about ideal which is the most important substructure of a ring.
- To study Polynomial ring and irreducibility of polynomial in a ring.

Syllabus Contents

Groups: Homomorphism of groups, Normal Subgroups, Quotient groups, Isomorphism theorems, Cayley's theorem, Generalized Cayley's theorem, Automorphism, Inner Automorphism and Automorphism groups, Finite groups, Simple groups, Direct product (internal and external), Group action on a set, Conjugacy classes and conjugacy class equation, p-groups, Cauchy's theorem, Sylow theorems and their applications.

Rings: Rings, commutative rings with identity, Prime and irreducible elements, Division ring, Ideals and Homomorphism, Isomorphism theorems, Quotient Rings, Prime and maximal Ideals, Relation between Prime and Maximal Ideals, Quotient field of an integral domain, Divisibility theory, Euclidean domain, Principle Ideal domain, Unique factorization Domain, Gauss Theory, Polynomial rings, Irreducibility of polynomials, Eisenstein's irreducibility criterion.

Outcomes: After studying this course the student

- Can find the class equation of a finite groups and using Sylow's theorem will be able to identify whether a group is simple or not.
- Can identify and construct examples of rings, fields, Quotient field.
- Using Eisenstein's irreducibility criterion will be able to verify whether a polynomial is reducible or irreducible in a polynomial ring.

References:

1. Dummit, D.S., Foote, R.M., Abstract Algebra, Second edition, John Wiley & Sons, 1999.
2. Herstein, I.N., Topics in Algebra, Wiley Eastern Ltd.
3. Malik, D.S., Mordesen, J.M., Sen, M.K., Fundamentals of Abstract algebra, McGraw Hill.
4. Jacobson, N., Basic Algebra, I & II, Hindustan Publishing Corporation, India.
5. Bhattacharya, P.B., Jain, S. K. & Nagpaul S. R., Basic Abstract Algebra, Cambridge.
6. Lang, S., Algebra.
7. Hungerford, T.W., Algebra, Springer.

8. Sen. M.K, Ghosh, S., and Mukhopadhyay, P., Topics in Abstract Algebra, University Press, 2006.

MSCMATHC104: ORDINARY DIFFERENTIAL EQUATIONS & SPECIAL FUNCTIONS

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objectives:

- To provide knowledge of ordinary differential equations required for practicing scientists and engineers.
- To identify ordinary and singular points.
- To find power series solutions about ordinary points and singular points.
- To acquire knowledge about greens functions and applications to boundary value problem.

Syllabus Contents

Ordinary Differential Equations:

First order system of equations: Well-posed problems, Existence and Uniqueness of the solution, Simple illustrations, Peano's and Picard's theorems (Statement only).

System of linear differential equations: Solution of homogeneous and non-homogeneous linear system of equations, Wronskian of vector functions, Fundamental set of solutions.

Non-linear differential equations: Autonomous system, Phase plane analysis, Critical Points, Types of critical points, Stability, Linearization, Liapunov stability, Limit cycles.

Adjoint equations of second order differential equations. Ordinary differential equations of Strum Liouville type, Characteristic value and Characteristic functions, Orthogonality theorem.

Special Functions:

Series Solution: Ordinary point and singularity of a second order linear differential equation in the complex plane, Fuch's theorem, Solution about an ordinary point, Solution of Hermite equation as an example, Regular singularity, Frobenius method- solution about a regular singularity.

Hypergeometric equation: Series solution near zero, one and infinity, Hypergeometric functions, Integral formula for the hypergeometric function, Differentiation of hypergeometric function.

Legendre equation: Series solution of Legendre equation, Legendre polynomial, Generating function, Rodrigue's formula, Recurrence relations, Its orthogonality, Expansion of a function in a series of Legendre Polynomials. Legendere functions of first kind and second kind, Laplace integral.

Bessel's equation: Series solution of Bessel's equation, Bessel's function, Generating function, Integral representation of Bessel's function, Recurrence relations.

Green's function and its properties, Green's functions for ordinary differential equations, Application to boundary value problems.

Outcomes:

- The learner will be able to explain the use of differential equations, to classify the differential equations
- They will be able to solve differential equations by power series method.

References:

1. Codington, E.A. and Levinson, N., Theory of Ordinary Differential Equation, McGraw-Hill.
2. Simmons, G.F., Differential Equations, Tata McGraw Hill
3. Ross, S.L., Ordinary Differential Equations, John Wiley & Sons
4. I.N. Sneddon., Special Functions of Mathematical Physics and Chemistry,
5. Rainville, E.D., Special Functions, Macmillan.
6. Lebedev, N.N., Special Functions and Their Applications.
7. Hartman, P., Ordinary Differential Equation, John Wiley and Sons.
8. Reid, W.T., Ordinary Differential Equation, John Wiley and Sons.

MSCMATHC105: CLASSICAL MECHANICS & CALCULUS OF VARIATIONS

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objectives:

- To know the concept of generalized co-ordinates,
- To have the knowledge of Lagrange's equation of motion, Hamilton's principle, Canonical transformations, Hamilton's equations of motion, Euler's dynamical equations, etc.
- To understand the concept of Calculus of Variations and its applications.

Syllabus Contents

Constrained motion: Generalised co-ordinates, Constraints, Types of Constraints, Forces of constraints, Classification of a Dynamical system, Virtual Work, Generalised Principle of D'Alembert, Generalised forces and generalized momentum, Expression for kinetic energy, Lagrange's equation of motion of first kind

Lagrangian mechanics: Lagrange's equations of motion for holonomic and non-holonomic systems, Velocity dependent potential, Dissipative forces, Rayleigh's dissipation function

Hamiltonian mechanics: Cyclic co-ordinates, Routh's process for the ignoration of co-ordinates and applications, Legendre dual transformation, Hamilton's canonical equations of motion

Variational principles: Action Integral, Hamilton's principle for conservative, non-holonomic system, Hamilton's principle for non-conservative, non-holonomic system, derivation of Hamilton's principle from Lagrange's equations, derivation of Lagrange's equations from Hamilton's principle, Principle of least action, Principle of energy

Canonical transformations: Generating functions and canonical transformations, Properties of canonical transformations, Condition of canonicality, Infinitesimal canonical transformations

Brackets: Poisson bracket, Lagrange bracket and their properties, Invariance of Poisson and Lagrange brackets under canonical transformations, Hamilton-Jacobi's equation, Hamilton's equations of motion in terms of Poisson bracket.

Calculus of Variations: Concept of variation, Linear functional, Deduction of Euler-Lagrange differential equation- Some special cases, Euler-Lagrange differential equation for n-dependent variables, Functional dependent on higher order derivatives, Functional dependent on functions of several variables.

Applications of calculus of variations to various problems: Shortest distance, minimum surface of revolution, Brachistochrone problem, geodesic, Isoperimetric problem, Calculus of variations for problems in parametric form, Variational problems with moving boundaries.

Outcomes: After successful completion of the course, the student would

- Acquire a deep knowledge of different types of principles of motion.
- Use this principles to real life problems and higher studies.
- Have a deep understanding of calculus of variations.

References:

1. Goldstein, H., Classical Mechanics, Pearson.
2. Rana N.C., Jog, P.S., Classical Mechanics.
3. Chorlton, F., Dynamics.
4. Synge and Graffith, Principle of Mechanics.
5. Gupta, K. C., Classical Mechanics of Particles and Rigid Bodies.
6. Gupta, A. S., Calculus of Variations with Applications.
7. Gelfand, I. M. and Fomin, S.V., Calculus of Variations.

SEMESTER-II

MSCMATHC201: TOPOLOGY

- **Full Marks: 50** ✧ **CA+ESE Marks: 10+40**
- **Credit: 4** ✧ **L - T –P : 4 - 0 - 0**

Objectives:

- To introduce basic concepts of point set topology, derived concepts, basis and sub-basis for a topology and order topology.
- To study continuity, homeomorphisms, open and closed maps, product topologies.
- To study the notions of connectedness, path connectedness, local connectedness, local path connectedness, convergence, countability axioms and compactness of spaces.

Syllabus Contents

Set Theory: Countable and uncountable sets, Schroeder-Bernstein Theorem, Cantor's Theorem, Cardinal numbers and Cardinal arithmetic, Continuum Hypothesis, Zorn's Lemma, Axioms of Choice, Well-Ordered Sets, Maximum Principle, Ordinal numbers.

Topological Spaces and Continuous functions: Topological spaces, Basis and sub-basis for a topology, Order Topology, Product Topology on X×Y, Subspace Topology, Interior Points, limits Points, Derived

Set, Boundary of a set, Closed sets, Closure and interior of a Set, Kuratowski closure operator and the generated topology, Continuous functions, Open Maps, Closed maps and Homeomorphism, Product Topology, Quotient Topology, Metric Topology, Complete Metric Spaces, Baire Category Theorem.

Connectedness and Compactness: Connected and path connected spaces, Connected sets in R, Components and path components, Local Connectedness, Compact Spaces, Compact sets in R, Compactness in metric spaces, Totally Bounded Spaces, Ascoli-Arzela Theorem, The Lebesgue Number Lemma, Local Compactness.

Outcomes: After successful completion of the course the student would be able to

- Determine interior, closure, boundary, limit points of subsets and bases and subbasis of topological spaces.
- Check whether a collection of subsets is a basis for a given topological spaces or not, and determine the topology generated by a given basis.
- Identify the continuous maps between two spaces and maps from a space into product space and determine common topological property of given two spaces.
- Determine the connectedness and path connectedness of the product of a arbitrary family of spaces.

References:

1. Munkers, J.R., Topology, Pearson.
2. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
3. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1995.
4. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
5. Steen, L., Seebach, J., Counter Examples in Topology, Holt, reinhart and Winston, New York.

MSCMATHC202: LINEAR ALGEBRA AND PRINCIPLES OF OPERATIONS RESEARCH

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Unit 1: Linear algebra

Total Marks: 25 (5 marks reserved for internal assessment)

Objectives:

- To analyze and solve a linear system of equations.
- To understand important characteristics of matrices such as rank, determinant, eigenvalues and eigenvectors etc.
- How to use characteristics of a matrix to solve a linear system of equations or study properties of a linear transformation.
- To gain knowledge about important concepts of vector spaces such as independence of vectors, basis, dimensions, orthogonality etc.
- To acquire the basic knowledge of the theory of Operation research and different types of methods for optimize the problems regarding real life situation.

Syllabus Contents

Vector spaces over a field, Dual space, Linear transformation in finite dimensional spaces, Matrix representation, The rank-nullity theorem, Adjoint of linear transformation, Eigenvalues and Eigenvectors, Characteristic and minimal polynomial, Diagonalization , Diagonalization of symmetric and Hermitian matrices, Cayley-Hamilton theorem, Reduction of a matrix to normal form, Jordan Canonical form. Sylvester's law of inertia, simultaneous reduction of two quadratic forms, applications to Geometry & Mechanics.

Inner product spaces: Cauchy-Schwatz inequality, orthogonal vectors and orthogonal complements, Orthonormal sets and Bases, Bessel's inequality, Gram-Schmidt orthogonolization method, Hermitian, Self-adjoint, Unitary and orthogonal transformations.

Outcomes: After studying this course the student should be able to perform the following

- Find the dimension and basis of a given vector space.
- Test independence of vectors.
- Determine the rank, eigenvalues and eigenvectors, diagonalization and different factorization of a matrix.
- Write down the matrix representing a linear transformation under a given basis and determine how the matrix changes if the basis changed.
- Determine the existence and uniqueness of the solution of a linear system.

References:

1. Hoffman and Kunze, Linear Algebra, Pearson.
2. Kumerason, S., Linear Algebra.
3. Lang, S., Linear Algebra.
4. Friedberg, Insel and Spence, Linear Algebra, Pearson.
5. Halmos., Finite Dimensional Vector Spaces.

Unit 2: Principles of Operations Research

Total Marks: 25 (5 marks reserved for internal assessment)

Objectives:

- To impart knowledge and understanding of fundamentals in Operational Research.
- To understand of project scheduling and management
- To provide students with a thorough understanding of basic inventory models;
- To provide the students with a comprehensive study of various application areas of inventory models through case studies and relevant examples.
- To provide the students with a rigorous framework to analyse queueing systems in real life.

Syllabus Contents

Operations Research: Introduction, Definition and Scope of Operations Research, Application of Operations research in different areas.

Revised simplex method: Standard forms of revised simplex method, Computational procedure, Comparison of simplex method and revised simplex method.

Sensitivity Analysis: Change in profit (or cost) contribution co-efficient, Change in availability of resources, Change in input output co-efficient, Addition and deletion of variables, Addition of constraints .

Bounded variable technique for L.P.P.

Project Scheduling by PERT/CPM: Introduction, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis.

Outcomes: After studying this course the student should be able to perform the following

- Identify the goals and objectives of inventory management
- Understand the various selective inventory control techniques and its applications
- Deep understanding of the theoretical background of queueing systems.
- To apply and extend queueing models to analyze real world systems

References:

1. Taha, H.A., Operations Research-An Introduction, Pearson.
2. Sarup, K., Gupta, P.K., and Mohan, Man, Operations Research, Sultan Chand & Sons.
3. Sharma, J.K., Opeartions Research, Mcmillan, India.
4. Sharma, S.D., Operation Research, Kedarnath & Ramnath, Meerut.

MSCMATHC203: PARTIAL DIFFERENTIAL EQUATIONS

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objectives:

- To understand partial differential equations, classification and methods of solution procedure
- To interpret the solutions of PDEs.
- To solve practical PDE problems with finite difference methods

Syllabus Contents

First order partial differential equations (PDE): Basic concepts- Quasilinear equations, Semilinear equations, Linear equations, Solutions: Cauchy's problem; Linear equations; Integral surfaces; Nonlinear equations; Cauchy's method of characteristics; Charpit's method; Hamilton-Jacobi equation.

Second order linear PDE: Classification; Reduction to normal form; Solutions- equation with constant coefficients; nonlinear equations of second order by Monge's method.

Hyperbolic Equations**:** The equation of vibration of a string. Formulation of mixed initial and boundary value problem. Existence, Uniqueness and continuous dependence of the solution to the solution to the initial conditions. D'Alembert's formula for the vibration of an infinite string. The domain of dependence, the domain of influence use of the method of separation of variables for the solution of the problem of vibration of a string. Investigation of the conditions under which the infinite series solution convergence and represents the solution. Riemann method of solution, problems, Transvers vibration of membrances. Rectangular and circular membranes problems.

Elliptic Equations: Occurrence of Laplace's equation. Fundamental solutions of Laplace's equation in two and three independent variables. Laplace equation in polar, Spherical polar and in Cylindrical polar co-ordinates, Minimum-maximum theorem and its consequences. Boundary value problems, Dirichlets and Neumann's interior and exterior problems uniqueness and continuous dependence of the solution on the boundary conditions. Use of the separation of variables method for the solution of Laplace's equations in two or three dimension. Interior and exterior Dirichlet's problem for a circle and a semi circle, steady state heat flow equation problems, Higher dimensional problems, Dirichlet's problem for a cube, Cylinder and sphere, Green's function for the Laplace equation in two and three dimension.

Parabolic Equations: Conduction of heat in a bounded strip, First boundary value problem, Maximum-Minimum theorem and its consequences, uniqueness, continuous dependence of the solution and existence of the solution. Conduction of heat in a infinite strip (Cauchy problem), Problems.

Outcomes:

- Be able to apply the fundamental concepts of Partial Differential Equations and the basic numerical methods for their resolution.
- To have knowledge to solve the problems of choosing the most suitable method.
- Formulate and solve in the field of Engineering.

References:

1. Sneddon, I.N., Elements of Partial Differential Equations, McGraw Hill.
2. Miller, Partial Differential Equations.John, F., Partial Differential Equations.
3. Amarnath, T., An Elementary Course in Partial Differential Equations, Narosa Pub.
4. Prasad P., Ravindran R., Partial Differential Equations, New Age International (p) Ltd.

MSCMATHC204: NUMERICAL ANALYSIS

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 4** ✧**L - T –P : 4 - 0 - 0**

Objectives:

- To enhance the problem solving skills using numerical methods.
- To handle large system of equations, non-linearity and and that are often impossible to solve analytically
- To solve differential equations by numerical methods

Syllabus Contents

Operators and their interrelationship. Shift, forward, backward, central differences, averaging operators, differential operators.

Polynomial approximation: Polynomial interpolation, Errors and minimizing errors, Hermite's interpolation, Piecewise polynomial approximation, Cubic spline interpolation, Chebyshev polynomials, Curve fitting by least square method, Use of orthogonal polynomials.

Numerical integration: Richardson extrapolation and Romberg's integration method, Gaussian quadrature, Gauss-Legendre and Gauss-Chebyshev integration rule, Quadrature formula for singular integrals.

Roots of polynomial equation: Graffae's root squaring method and Bairstow's method, Solution of a system of non-linear equations by fixed point method and Newton Raphson method, Convergence and rate of convergence.

Solution of ordinary differential equation: Fourth order R-K method for the solution of second order ordinary differential equations and simultaneous first order ordinary differential equations. Adam-Bashforth-Moulton and Milne's predictor corrector method to solve first order initial value problems.

Solution of second order boundary value problems by finite difference method and Shooting method. Eigenvalue problems for linear second order ordinary differential equations.

Solution of a system of linear equations: Matrix inversion method, General iterative method, Jacobi and Gauss Seidal method, Necessary and sufficient conditions for convergence, LU decomposition method, Solution of tri-diagonal system of equations, Ill-conditioned linear systems, Relaxation method,

Eigenvalue problems of a matrix: Determination of eigenvalues by- Power method, Jacobi's method for Eigenvalues of symmetric matrices, Eigenvalues of symmetric tri-diagonal matrix, Bounds of Eigenvalues, Gershgorin's circle theorem.

Solution of partial differential equations: Finite difference approximations to partial derivatives, Schmidt explicit and Crank-Nicolson implicit method for the solution of parabolic equations in one space coordinate, Implicit finite difference method for solution of Hyperbolic equation in one space co-ordinate, Solution of elliptic equation in two variables, convergence and stability analysis.

Outcomes:

- Understand numerical techniques to find the roots of algebraic equations and system of linear equations.
- Understand the solution procedure of initial and boundary value problem
- Have skill to solve partial differential equations.

References:

1. Hildebrand, F. B., Introduction to Numerical Analysis.
2. Atkinson, Numerical Analysis.
3. Gupta, A and Basu, S.C., Numerical Analysis.
4. Jain, Iyenger and Jain, Numerical Methods for Scientific and Engineering Computation.
5. Ralston, A., A first course in Numerical Analysis, McGraw-Hill, N.Y., 1965.

Minor Elective

MSCMATHMIE201: OPERATIONS RESEARCH

- **Full Marks: 50** — **CA+ESE Marks: 10+40**
- **Credit: 4** — **L - T –P : 4 - 0 - 0**

Objectives:

- To impart knowledge and understanding of fundamentals in Operational Research.
- To understand of project scheduling and management
- To provide students with a thorough understanding of basic inventory models;
- To provide the students with a comprehensive study of various application areas of inventory models through case studies and relevant examples.
- To provide the students with a rigorous framework to analyse queueing systems in real life.

Syllabus Contents

Operations Research: Introduction, Definition and Scope of Operations Research, Application of Operations research in different areas.

Project Scheduling by PERT/CPM: Introduction, Basic difference between PERT and CPM, Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis Sequencing Models: The mathematical aspects of Job sequencing and processing problems, Processing n jobs through Two-machines, processing n jobs through m machines.

Inventory Control: Historical background and Introduction of this topic, Nature of inventory problems, Features of inventory system, Definition of inventory problem. Important parameters associated with inventory problems, Variables in inventory problems, Inventory model building, Deterministic inventory models with-No shortage, Shortage.

Queuing Theory: Introduction, Features of Queuing systems, Queue disciplines, The Poisson process (Pure birth process), Arrival distribution theorem, Properties of Poisson process, Solution of Queuing models: {(M/M/1):($\infty|FCFS$)}, {(M/M/1):($n|FCFS$)}, {(M/M/s):($\infty|FCFS$)}, {(M/M/s):($n|FCFS$)}.

Outcomes:

- Identify the goals and objectives of inventory management
- Understand the various selective inventory control techniques and its applications
- Deep understanding of the theoretical background of queueing systems.
- To apply and extend queueing models to analyze real world systems.

References:

1. Sharma, J.K., Opeartions Research, Mcmillan, India.
2. Taha, H.A., Operations Research-An Introduction, Pearson.
3. Sarup, K., Gupta, P.K., and Mohan, Man, Operations Research, Sultan Chand & Sons.
4. Sharma, S.D., Operation Research, Kedarnath & Ramnath, Meerut.

SEMESTER-III

MSCMATHC301: FUNCTIONAL ANALYSIS

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 4** ✧**L - T –P : 4 - 0 - 0**

Objectives:

- To introduce and discuss the basic tools of Functional Analysis involving normed spaces, Banach spaces and Hilbert spaces, their properties dependent on the dimension and the bounded linear operators from one space to another**.**
- To taught about some important features of metric spaces such as completion of a metric space, Baire Category theorem, equicontinuous family of functions, Arzela-Ascoli's theorem etc.

Syllabus Contents

Baire category theorem. Normed linear spaces, continuity of norm function, Banach spaces, Spaces C^n, C[a,b](with supmetric), c_0, l_p, ($1\leq p\leq \infty$) etc.

Linear operator, boundedness and continuity, examples of bounded and unbounded linear operators.

Banach contraction Principle- application to Picards existence theorem and Implicit function theorem.

Inner product, Hilbert spaces, examples such as l_2 spaces, $L_2[a,b]$ etc; C-S inequality, Parallelogram law, Pythagorean law, Minkowski inequality, continuity and derivatives of functions from R^m to R^n.

Completion of Metric space. Equicontinuous family of Functions. Compactness in C[0,1] (Arzela-Ascoli's Theorem). Convex sets in linear spaces.

Properties of normed linear spaces. Finite dimensional normed linear spaces. Riesz's Lemma, and its application in Banach spaces. Convergence in Banach spaces. Equivalent Norms and their properties.

Principle of Uniform Boundedness (Banch-Steinaus), Open Mapping theorem. Closed graph theorem, Hahn Banach theorem.

Outcomes: After studying this course the student will be able to

- Verify the requirements of a norm, completeness with respect to a norm, relation between compactness and dimension of a space, check boundedness of a linear operator and relate to continuity, convergence of operators by using a suitable norm, compute the dual spaces.
- Distinguish between Banach spaces and Hilbert spaces, decompose a Hilbert space in terms of orthogonal complements, check totality of orthonormal sets and sequences, represent a bounded linear functional in terms of inner product.
- Extend a linear functional under suitable conditions, compute adjoint of operators, check reflexivity of a space, ability to apply uniform boundedness theorem, open mapping theorem and closed graph theorem.

References:

1. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
2. Aliprantis, C.D., Burkinshaw, O., Principles of Real Analysis, 3rd Edition, Harcourt Asia Pvt Ltd.
3. Goffman, C., Pedrick, G., First Course in Functional Analysis, PHI, New Delhi, 1987.
4. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966.
5. Taylor, A.E. Introduction to Functional Analysis, John Wiley and Sons, New York, 1958.
6. Conway, J.B., A course in Functional Analysis, Springer Verlag, New York, 1990.

MSCMATHC302: MECHANICS OF CONTINUA

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objectives:

- To analyses stress and strain of a continuum body.
- To identify the knowledge of equation of motion of a deformable body.
- To understand strain energy density function.

Syllabus Contents

Analysis of stress: Notion of a continuum and deformable bodies, Body and surface forces, Cauchy's stress principle, Stress vector, Specification of stress at a point, stress tensor, The stress vector-stress tensor relationship, Equation of equilibrium, Symmetry of stress tensor, Rule of transformation of stress components, Principal stresses and principal direction of stresses, Stress invariants, Stress quadric of Cauchy, Maximum normal and shearing Stresses, Mohr's circle.

Analysis of strain: Deformation Gradients, Finite strain tensor, Infinitesimal strain components, Geometrical interpretation of infinitesimal strain components, Principal strain and principal axes of strain, Compatibility of strain components in three dimensions.

Motion of deformable bodies: Lagrangian and Eulerian approaches to study the motion of continua. Material derivative of a volume integral, Equation of continuity, Equation of angular momentum, energy equation.

Constitutive equations: Ideal materials, Generalized Hooke's law, Elastic Moduli, Equation of motion and equilibrium in terms of displacement components. Beltrami-Michell compatibility equations, Strain energy density function.

Inviscid fluid, Circulation, Kelvin's Energy Theorem, Constitutive equations for viscous fluid. Navier and Stokes equations of motion.

Outcomes:

- Have the knowledge of stress and strain of continuum body
- Identify the stress strain relationship and compatibility equation
- Have the knowledge about constitutive equations for viscous fluid.

References:

1. Chung, T. J., Continuum Mechanics, Prentice-Hall.
2. Fung, Y.C., A first course in continuum mechanics.
3. Eringen, A.C., Non-linear Theory of Continuous Media, McGraw-Hill.
4. Chorlton, F., A text book of Fluid Mechanics.
5. Sedov, L.I., A course in continuum mechanics, Vol-I.

MSCMATHC303: COMPUTER PROGRAMMING IN 'C': THEORY

✧ Full Marks: 50 **✧CA+ESE Marks: 30+20**

✧ Credit: 2 **✧L - T –P : 0 - 0 - 4**

Objectives:

- To acquire knowledge of different computer languages.
- To understand basic structures, characters, identifier etc. in C language.
- To write flow chart and corresponding C-programme for solving numerical and decision making problems.

Syllabus Contents

Programming in C: Introduction, Basic structures, Character set, Keywords, Identifiers, Constants, Variable-type declaration, Operators: Arithmetic, Relational, Logical, assignment, Increment, Decrement, Conditional.
Operator precedence and associativity, Arithmetic expression, Evaluation and type conversion, Character reading and writing, Formatted input and output, Statements.

Decision making (branching and looping) – Simple and nested *if, if – else, switch, while, do-while, for* statements.

Concept of array variables, String handling with arrays – reading and writing, String handling functions.

User defined functions, cell-by-value, cell-by-reference function and their uses, Return values and their types, Nesting of functions, Recursion.

Structures: Declaration, initialization, nested structure, array of structures, array within structures.

Pointers: Declaration, initialization, Accessing variables through pointer, pointer arithmetic, pointers and arrays.

Outcomes: After successful completion of the course the student will able to

- To grow ability to define and manage data structures based on problem subject domain.
- Write flow chart and C-programme of different decision making problem.
- Distinguished between real variable and integer variable, different types of loops, cell-by value and cell-by functions, etc.
- To solve the problems which require array variables.

References:

1. E. Balaguruswamy, Programming *in ANSI C*, Tata McGraw-Hill, 2011.
2. B. S. Gottfried, Programming *with C*, Tata McGraw-Hill, 2011.
3. K. R. Venugopal and S. R. Prasad, *Programming with C*, TMH, 1997.
4. C. Xavier, *C Language and Numerical Methods*, New Age International (P) Ltd. Pub, 2007

MSCMATHC304: COMPUTER AIDED NUMERICAL PRACTICAL

Total marks: 50 (Problem-30 marks, Viva-10 marks & Sessional-10 marks) Credit: 2

Objectives:

- To develop problem solving skills.
- To acquire knowledge of computer language.
- To solve different numerical problems using C language.

Problems:

i. Integration by Romberg's method.
ii. Initial value problem for first ODE by Milne's method
iii. Initial value problem for second order ODE by 4th order Runge-Kutta method.
iv. B.V.P for second order ODE by finite difference method and Shooting method.
v. Dominant Eigen-Pair of a real matrix by power method (largest and least).

vi. Solution of one dimensional Wave equation by finite difference method.
vii. Parabolic equation (in two variables) by two layer explicit method.

Outcomes: After successful completion of the course the student will able to

- Solve different Numerical problems which are not solving easily.
- Acquire a practical knowledge which helps to solve the problems in higher studies.

References:

1. Kumar, R., Programming with FORTRAN-77.
2. Jain and Suri, FORTRAN -77 Programming Language Including FORTRAN-90.
3. Xavier, C., C Language and Numerical Methods, New Age International Pvt. Ltd.
4. Balagurusamy, E., Programming in C, TMH.

Major Electives

MAJOR ELECTIVE I & MAJOR ELCTIVE II

MSCMATHMJE301: ADVANCED COMPLEX ANALYSIS I

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objective

This course is aimed to provide the theories for functions of a complex variable in the advanced level. It begins with the introduction of the functions M(r), A(r) and the growth of log M(r). Two growth indicators order and type of an entire function are introduced and their representation in terms of Taylor coefficients is discussed. The notion of infinite product representation of an entire function is discussed by using Weierstrass' factorisation theorem and Hadamard's factorisation theorem. The concept of canonical product representation of an entire function is discussed and Borel's theorem is introduced. Schottky's theorem (without proof), Little Picard's theorem are also introduced. The concept of analytic continuation is introduced and structure of Riemann surface is given.

Syllabus Contents

The Functions M(r), A(r), Hadamard Theorem on Growth of log M(r), Schwarz Inequality, Borel-Caratheodory Inequality.

Entire functions, Growth of an entire function, Order and type and their representations in terms of the Taylor Coefficients, Distribution of zeros, Schottky's theorem (without proof), Picard's Little theorem, Weierstrass Factor theorem, The exponent of convergence of zeros, Hadamard factorization theorem, Canonical product, Borel's first theorem, Borel's second theorem (statement only).

Analytic continuation, Natural boundary, Analytic element, Global analytic function, Concept of analytic manifolds, Multiple valued conditions, Branch points and Branch cut, Riemann surfaces.

Outcomes:

Upon successful completion, students will have the knowledge and skills to:

- Explain the concepts of growth of entire function.
- Represent an entire function in the infinite product.
- Demonstrate Riemann surface by the use of analytic continuation.

References:

1. Conway, J. B., Functions of one complex variables, Second edition, Narosa Pub.
2. Sarason, D., Complex function theory, Hindustan book agency, Delhi, 1994.
3. Ahlfors, L.V., Complex analysis, McGraw Hill, 1979.
4. Rudin, W., Real and complex analysis, Mc Graw Hill, 1966.
5. Hille, E., Analytic function theory, Gonn and Co. 1959.
6. Titchmarsh, E.C., The Theory of Functions, Oxford University Press, London
7. Markusevich, A.I., Theory of Functions of A Complex Variable, Vol. I,II,III.
8. Copson, E.T., An Introduction to the Theory of Functions of a Complex Variable.
9. Kaplan, W., An Introduction to Analytic Functions.

MSCMATHMJE302: ADVANCED FUNCTIONAL ANALYSIS I

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- To familiarize with the concept of topological vector space which is one of the most important structures in Functional analysis.
- To discuss about locally convex topological vector space which can be generated from a family of semi-norms and also from a locally convex space one can construct a separating family of seminorms.

  To taught convexity structure in Topological vector space, Banach space, Hilbert space.

Syllabus Contents

Topological vector spaces, Local base and its properties, Separation properties, Locally compact topological vector spaces and its dimension. Convex Hull and representation Theorem, Extreme points, Symmetric sets, Balanced sets, absorbing sets, Bounded sets in topological vector space. Linear operators over topological vector space, Boundedness and continuity of Linear operators, Minkowski functional, Hyperplanes, Separation of convex sets by Hyperplanes, Krein-Milman Theorem on extreme points.

Locally convex topological vector spaces, Criterion for norm ability, Semi norms, Generating family of semi norms in locally convex topological vector spaces. Barreled spaces and Bornological spaces. Criterion for locally convex topological vector spaces to be (i) Barreled and (ii) Bornological.

Strict convexity and uniformly convexity of a Banach space. Uniform Convexity of a Hilbert Space.

Reflexivity of a uniformly convex Banach space, Weierstrass approximation theorem in C [a,b].

Outcomes: After completing this course a student will be able to

- Verify whether a topological vector space is normable or not.
- Understand that existence of convex local base at zero vector is strong enough for metrizablity of a topological vector space.
- Realize that every continuous function defined on any closed interval can be approximated by a polynomial.

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Schaffer, A.A.,Topological Vector Spaces, Springer, 2nd Edn., 1991
3. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
4. Kreyszig, E., Introductory Functional Analysis with Applications, Wiley Eastern, 1989
5. Diestel, Application of Geometry of Banach Spaces
6. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985
7. Simmons, G. F.,Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963

MSCMATHMJE303: ADVANCED TOPOLOGY

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objectives:

- To familiarize with the concept of countability and separation axioms, Nets and filters, etc.
- To discuss different topological spaces such as Regular, Normal, Tychonoff, Metrizable, Baire, Uniform space etc.
- To study the topological property using different standard theorems such as Uryshon metrization theorem, Imbedding theorem etc.
- To give an idea of compactification and their types.

Syllabus Contents

Countability and Separation Axioms: Countability axioms, The separation axioms, Equation spaces, Lindelöf spaces, Regular spaces, Normal spaces, Urysohn Lemma, Tietze extension theorem.

Nets and Filters: Directed sets, Nets and Subnets, Convergence of a Net, Ultranets, Partially ordered sets and filters, Convergence of a filter, Ultrafilters, Basis and subbase of a filter, Nets and Filters in Topology.

Tychonoff Theorem & Compactification: Tychonoff theorem, Completely regular spaces, Local compactness, One-point compactification, Stone-Cech compactification.

Metrization: Urysohn Metrization theorem, Topological imbedding, Imbedding theorem of a regular space with countable base, Partitions of unity, Topological m-Manifolds, Imbedding theorem of a compact m-Manifold in R^n. Local finiteness, Nagata-Smirnov Metrization theorem, Paracompactness, Stone's theorem, Local metrizability, Smirnov Metrization theorem, Uniform spaces.

Compactness in metric spaces, Equicontinuity, Pointwise and compact convergence, The compact-open topology, Stone-Weierstrass theorem, Ascoli's theorem, Baire spaces, A nowhere differentiable function.

Outcomes: After successful completion of the course the will able to

- Define different special types of Topological spaces, Nets and filters etc.
- Determine the relation among different topological spaces such as Regular, Normal, Tychonoff, Metrizable, Baire, Uniform space etc.
- Test a space is metrizable or not.
- State different standard theorems of topological space such as Uryshon metrization theorem, Imbedding theorem etc.
- Extend a topological space to a compact space using the idea of compactification.

References:

1. Munkers, J.R., Topology, Pearson
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Simmons, G.F., Introduction to Topology and Modern analysis, McGraw-Hill, 1963.
4. Kelley, J.L., General topology, Van Nostrand Reinhold Co., New York, 1995.
5. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
6. Steen, L., Seebach, J., Counter Examples in Topology, Holt, reinhart and Winston, New York.

MSCMATHMJE304: DIFFERENTIAL GEOMETRY OF MANIFOLDS-I

- **Full Marks: 50** ✧ **CA+ESE Marks: 10+40**
- **Credit: 5** ✧ **L - T –P : 4 - 1 - 0**

Objectives:

After a course in Analytic Geometry and Differential geometry of curves at undergraduate level, Differential Geometry is a core component of a post graduate syllabus which introduces the methods of differential manifolds, tensor analysis, vector fields, Lie Group, Lie Algebra etc. The objective is to prepare the students for further coursework and research in geometry in future.

Syllabus Contents

Definition and examples of differentiable manifolds. Tangent spaces. Jacobian map. One parameter group of transformation. Lie derivatives. Immersions and imbedding. Distributions.

Exterior algebra. Exterior derivative.

Topological groups. Lie groups and Lie algebras. Product of Two Liegroups. One parameter subgroup and exponential maps. Examples of Liegropus. Homomorphism and Isomorphism.

Lie transformation groups, General linear group.

Principal fibre bundle. Linear frame bundle. Associated fibre bundle. Vector bundle. Tangent bundle. Induced bundle. Bundle homeomorphisms.

Outcomes:

After completing this course, a student will be able to understand

- Lie Group, Lie Algebra
- Symplectic Geometry, Poisson Geometry
- Global Analysis
- Several Complex Variable,
- Hyperbolic Geometry,
- Projective and Algebraic Geometry
- Mathematical Physics, Relativity, Cosmology and Standard Models.

References:

1. Mishra, R. S., A course in tensor with applications to Riemannian Geometry, Pothishala Pub.
2. Mishra, R. S., Structures on a differentiable manifold and their applications, Chandrama Prakashan, Allahabad, 1984.
3. Sinha, B. B., An Introduction to Modern Differential Geometry, Kalyani Publishers, New Delhi,
4. Yano, K. and Kon, M., Structures of Manifolds, World Scientific Publishing Co. Pvt. Ltd., 1984
5. De, U.C., Shaikh, A. A., Differential Geometry of Manifolds, Narosa Publishing House Pvt. Ltd.

MSCMATHMJE305: FIELD THEORY

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- Fields forms one of the important and fundamental algebraic structures and has an extensive theory dealing mainly with field extensions which arise in the study of roots of polynomials.
- In this course we study fields in detail with a focus on Galois theory which provides a link between group theory and roots of polynomials.

Syllabus Contents

Field Extensions: Algebraic and Transcendental Extensions, Finite Extensions, Algebraic Closure of a field, Algebraically Closed Field, Splitting Field of a polynomial, Normal Extensions, Separable Extensions, Impossibility of some constructions by straightedge and compass.

Finite Fields and their properties, Galois group of automorphism and Galois Theory, Solution of polynomial equations by radicals, Insolvability of the general equation of degree 5 (or more) by radicals.

Outcomes: After studying this course the student will be able to

- identify and construct examples of fields, distinguish between algebraic and transcendental extensions, characterize normal extensions in terms of splitting fields and prove the existence of algebraic closure of a field.
- characterize perfect fields using separable extensions, construct examples of automorphism group of a field and Galois extensions as well as prove Artin's theorem and the fundamental theorem of Galois theory.
- classify finite fields using roots of unity and Galois theory and prove that every finite separable extension is simple.
- use Galois theory of equations to prove that a polynomial equation over a field of characteristic is solvable by radicals iff its group (Galois) is a solvable group and hence deduce that a general quintic equation is not solvable by radicals.

References:

1. Dummit, D.S., Foote, R.M., Abstract Algebra, Second edition, John Wiley & Sons, 1999.
2. Herstein, I.N., Topics in Algebra, Wiley Eastern Ltd.
3. Goldhaber, J.K, Ehrlich, G., Algebra, The Macmillan Company, Collier-Macmillan Limited.
4. Jacobson, N., Basic Algebra, I & II, Hindustan Publishing Corporation, India.
5. Malik, D.S., Mordesen, J.M., Sen, M.K., Fundamentals of Abstract algebra, MCGraw Hill.
6. Hungerford, T.W., Algebra, Springer.

MSCMATHMJE306: OPERATOR THEORY I

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- To familiarize with the concept of Resolvent Set and different types of Spectrums.
- To discuss different theorems to find the spectrum of a bounded linear operator and its adjoin.
- To study the behavior of compact linear operator.
- To give an idea of banach algebra and its properties.

Syllabus Contents

Bounded Linear Operators: Resolvent Set, Spectrum, Point spectrum, Continuous spectrum, Residual spectrum, Approximate point spectrum, Spectral radius, Spectral properties of a bounded linear operator, Spectral mapping theorem for polynomials. Numerical range, Numerical radius, Convexity of numerical range, Closure of numerical range contains the spectrum, Relation between the numerical radius and norm of a bounded linear operator.

Banach Algebra: Definition of normed and Banach algebra and examples, Singular and non-singular elements, The spectrum of an element, The spectral radius.

Compact linear operators: Spectral properties of compact linear operators on a normed linear space, Operator equations involving compact linear operators, Fredholm alternative theorem, Fredholm alternative for integral equations. Spectral theorem for compact normal operators.

Outcomes: After successful completion of the course the will able to

- Define different special types of spectrums and state their relation.
- Determine the spectral radius of different types of operators.
- Test the behavior of an operator.
- State different standard theorems involving bounded linear operators.

References:

1. Kreyszig, E., Introductory Functional Analysis with Appliactions, John Wiley and Sons.
2. Bachman, G., and Narici, L., Functional Analysis, Dover Publications.
3. Taylor, A.E. Introduction to Functional Analysis, John Wiley and Sons, New York, 1958.
4. Dunford, N., and Schwarts, J.T., Linear Operators-3, John Willey and Sons.
5. Halmos, P.R., Introduction to Hilbert Space and the theory of Spectral Multiplicity, Chelsea Publishing Co., N.Y.

MSCMATHMJE307: BIOMATHEMATICS I

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- Demonstrate an understanding of the foundations of biomathematics
- To gain experience with the scientific practice of mathematical modeling.
- To understand real-world applications of scientific modeling.

Syllabus Contents

Mathematical Model of Population Biology or Ecology

Mathematical models: Deterministic and Stochastic. Single species population models. Population growth- An age structure model.

Interaction between two species: Host-Parasite type of interaction, Competitive type of interaction. Trajectories of interaction of H-P and competitive types between two species. Effect of migration on H-P interaction. Some consequences of Lotka-Volterra equation.

Generalized L-V equation. Pure birth process. Pure death process. Birth and Death process.

The logistic models with the effect of time-delay. Stability of equilibrium position for the logistic model with general delay function. Stability of logistic model for discrete time lag.

Linear birth-death-immigration-emigrationprocesses.

Host-Parasite models with time delay

Mathematical Theory of Epidemics

Introduction; Some basic definitions. Simple epidemic, General epidemic. KArmack-McKendrik threshold theorem. Recurring epidemic.

Control of epidemic. Stochastic epidemic model without removal

Epidemic model with multiple infections. Stochastic epidemic model with removal. Stochastic epidemic model with removal, immigration and emigration. Special discussion on the stochastic epidemic model with carriers.

Outcomes:

- Have the knowledge of modelling of exponentially-growing or -declining population.
- Use the model to recommend appropriate action for population management.
- Have the basic knowledge of Mathematical Theory of Epidemic.

References:

1. Kapur, J. N., Mathematical Models in Biology and Medicine, East West Press Pvt. Ltd (1985)
2. MacDonald, D. A., Blood Flow in Arteries, the Williams and Wilkins Company, Baltimore.
3. Fung, Y.C., Biomechanics of Soft Biological Tissues, Springer Verlag.
4. Habermann, R., Mathematical Models, Prentice Hall.
5. Poole, R. W., An Introduction to Quantitative Ecology, McGraw- Hill.
6. Pielou, E. C., An Introduction to Mathematical Ecology, Wiley, New York.
7. Rosen, R., Foundation of Mathematical Biology (Vol I & II), Academic Press.

MSCMATHMJE308: COMPUTATIONAL FLUID DYNAMICS I

- **Full Marks: 50** — **CA+ESE Marks: 10+40**
- **Credit: 5** — **L - T –P : 4 - 1 - 0**

Objectives:

- To understand the finite difference method and the finite element method on various computational problems in fluid dynamics
- To study first order wave equation
- To have knowledge of solving Dirichlet problem by finite volume method.

Syllabus Contents

Finite difference method: Treatment of model equations of parabolic, hyperbolic, elliptic types. Explicit and implicit schemes. Truncation error, consistency, convergence, stability (Von Neumann stability analysis only) of model question with appropriate initial and boundary conditions. Thomas algorithm, ADI method for 2-D heat conduction problem. Splitting and approximate factorization for 2-D Laplace equation. Multigrid method.

First order wave equation. Upwind scheme, consistency, CFL stability condition. First order hyperbolic system Hyperbolic conservation laws. Lax-Wendorf and McCormack schemes. Convection- diffusion equation. Stability. Finite - Volume method: preliminary concepts. Flux computation across quadrilateral cells. Reduction of a boundary value problem to algebraic equation. Illustrative example, like solution of Dirichlet problem for 2-D Laplace equation by finite volume method.

Outcomes:

- Able to identify differential equations for flow phenomena and numerical methods for their solution.
- Able to use and develop flow simulation software for the most important classes of flows in engineering and science.
- Able to critically analyze different mathematical models and computational methods for flow simulations.

References:

1. Niyogi, P., Chakraborty, S. K. and Laha, M. K., Introduction to Computational Fluid Dynamics, Pearson.
2. Fletcher, C. A. J., Computational Techniques for Fluid Dynamices, Vol-1 and Vol-II, Springer.
3. Peyret, R., and Taylor, T. D., Computational Methods for Fluid Flow, Springer 1983.
4. Thompson, J.F., Warsi, Z.U.A. and C.W. Martin, C.W., Numerical Grid Generation, Foundation and Applications, North Holland 1985
5. Landau, L. D., Lifshitz, E. M., Fluid Mechanics, Trans, Pergamon Press 1989
6. Schlichting, H., Gersten, K., Boundary – Layer Theory, 8^{th} Ed., Springer 2000

MSCMATHMJE309: FLUID MECHANICS I

✧ Full Marks: 50 **✧CA+ESE Marks: 10+40**

✧ Credit: 5 **✧L - T –P : 4 - 1 - 0**

Objectives:

- To describe the motion of fluids.
- To identify derivation of basic equations of fluid mechanics and apply
- To know about Irrotational motion in two and three dimensions
- To apply the equation of the conservation of energy.

Syllabus Contents

Lagrange's and Euler's methods in fluid motion. Equation of motion and equation of continuity, Boundary conditions and boundary surface, Stream lines and path of particles. Irrotational and rotational flows, velocity potential. Bernoulli's equation. Impulsive action. Equation of motion and equation of continuity in orthogonal curvilinear coordinate. Euler's momentum theorem and D' Alemberts Paradox.

Theory of irrotational motion. Flow and circulation. Permanence irrotational motion. Connectivity of regions of space. Cyclic constant and acyclic and cyclic motion. Kinetic energy. Kelvin's minimum energy theorem. Uniqueness theorem.

Irrotational motion in two and three dimensions.

Function. Complex potential, sources, sinks, doublets and their images. Circle theorem. Theorem of Blasius. Motion of circular and elliptic cylinders. Circulation about circular and elliptic cylinder. Steady streaming with circulation. Rotation of elliptic cylinder.

Theorem of Kutta and Juokowski. Conformal transformation. Juokowski transformation. The Schwarz Christoffel theorem.

Motion of a sphere. Stoke's stream function. Source, sinks, doublets and their images with regard to a plane and sphere.

Vortex motion. Vortex line and filament. Equation of surface formed by streamlines and vortex lines in case of steady motion. Strength of a filament. Velocity field and kinetic energy of a vortex system. Uniqueness theorem. Rectilinear vortices. Vortex pair. Vortex doublet. Image of a vortex with regard to a plane and a circular cylinder. Angle infinite row of vortices. Karman's vortex street.

Waves: Surface waves. Paths of particles. Energy of waves. Group velocity. Energy of a long wave.

Outcomes:

- Will be able to identify Lagrange's and Euler's methods in fluid motion
- Identify Velocity field and kinetic energy of a vortex system
- Identify how to derive basic equations and know the related assumptions.

References:

1. Ramsay, A.S., Hydrodynamics (Bell).
2. Lamb, H., Hydrodynamics (Cambridge)
3. Landau, L.D., Lifchiz, E.M., Fluid Mechanics (Pergamon), 1959
4. Milne-Thomson, I.M., Theoretical Hydrodynamics
5. Chorlton, F., Textbook of Fluid Dynamics.

MSCMATHMJE310: MECHANICS OF VISCOUS FLUID AND BOUNDARY LAYER THEORY I

✧ Full Marks: 50 **✧CA+ESE Marks: 10+40**

✧ Credit: 5 **✧L - T –P : 4 - 1 - 0**

Objectives:

Syllabus Contents

Mechanics of viscous fluids: Viscous fluids, velocity strain- tensor and stress-strain relations for fluids (statement of relations only). The Navier- Stokes equation of motion in Cartesian Co-ordinates and statements of its equivalent forms in spherical, polar and cylindrical Co- ordinates. Dissipation of energy due to viscosity, steady motion between parallel planes, Theory of lubrication, steady motion in a tube of different cross-section. vorticity in viscous fluids, Circulation in viscous fluids. diffusion of vorticity, steady flow past a fixed sphere, Dimensional Analysis, Reynolds number, steady motion of a viscous fluid dueto a slowly rotating sphere.

Two Dimensional Motions: Equation satisfied by the stream function for a motion under conservative fields of external forces, Hamel's equation, Logarithmic spirals.

Three Dimensional Motions: Stokes' solution for a slow steady parallel flow past a sphere, stream function and the flow pattern, Oseen's criticism solution for slow steady parallel flow past sphere and past a circular cylindrical.

Outcomes:

- Identify the Navier- Stokes equation of motion in Cartesian Co-ordinates
- Have the knowledge of vorticity and Circulation in viscous fluids
- To have knowledge about two and three Dimensional Motions of fluids.

References:

1. Thomson, M., Theoretical Hydrodynamics .
2. Lamb, H., Hydrodynamics.
3. Besant, W.H., Ramsay, A.S., A Treatise on Hydrodynamics Part-II.
4. Chorlton, F., Text book of Fluid Dynamics.

MSCMATHMJE311: OPERATIONS RESEARCH I

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objectives:

- To idenfy and solve integer programming problems
- To know about the mathematical aspects of Job sequencing and processing problems
- To solve nonlinear programming problems
- Identify the goals and objectives of inventory management
- To apply and extend inventory models to analyse real world systems.

Syllabus Contents

Integer Programming: Standard form of Integer Programming, The concept of cutting plane for linear integer programs, Gomory's cutting plane method, Gomory's All-Integer Programming Method, Branch-and-Bound Algorithm for general integer programs.

Sequencing Models: The mathematical aspects of Job sequencing and processing problems, Processing n jobs through Two-machines, processing n jobs through m machines.

Optimal Control: Performance indices, Methods of calculus of variations, simple optimal problems of mechanics.

Non-linear Programming: Formulation of Non-linear programming problem, Unconstrained optimization, Optimization with equality constraints, Kuhn-Tucker conditions for constrained optimization.

Quadratic Programming: Wolfe's modified simplex method, Beale's method. Convex Programming.

Inventory Control: Historical background and Introduction of this topic, Nature of inventory problems, Features of inventory system, Definition of inventory problem. Important parameters associated with inventory problems, Variables in inventory problems, Inventory model building, Deterministic inventory models with-No shortage, Shortage, Multi-item inventory models with constraints probabilistic Models-single period probabilistic models-without setup cost, with setup cost.

Outcomes:

- Identify job sequencing problems and able to solve
- Formulate real-world problems as nonlinear programming model
- Understand the various selective inventory control techniques and its applications.

References:

5. Hadley, G., Nonlinear and Dynamic Programming, Pearson.
6. Rao, S.S., Optimization Theory and Application, Wiley Eastern.
7. Taha, H.A., Operations Research-An Introduction, Pearson.
8. Sarup, K., Gupta, P.K., and Mohan, Man, Operations Research, Sultan Chand & Sons.
9. Dano, S., Nonlinear and Dynamic Programming.
10. Sharma, J.K., Opeartions Research, Mcmillan, India.
11. Sharma, S.D., Operation Research, Kedarnath & Ramnath, Meerut.

MSCMATHMJE312: QUANTUM MECHANICS I

- **Full Marks: 50** — **CA+ESE Marks: 10+40**
- **Credit: 5** — **L - T –P : 4 - 1 - 0**

Objectives:

- To analyze some real problem and to formulate the conditions of theory of elasticity application
- To execute a reasonable choice of parameters of the model (geometry, material properties, boundary conditions)
- To analyze the result of solution by standard computational programs.

Syllabus Contents

Fundamental ideas of quantum mechanics: Nature of the electromagnetic radiation; Wave-particle duality - double-slit experiment, quantum unification of the two aspects of light, matter waves; Wave functions and Schrodinger equation; Quantum description of particle - wave packet, uncertainty relation.

Mathematical formalism of quantum mechanics: Wave function space – bases, representation; State space – bases, representation; Observables – **R** and **P** observables; Postulates of quantum mechanics.

Physical interpretation of the postulates: Statistical interpretation – expectation values, Ehrenfest theorem, uncertainty principle; Physical implications of the Schrodinger equation - evolution of physical systems, superposition principle, conservation of probability, equation of continuity; Solution of the Schrodinger equation – time evolution operator, stationary state, time-independent Schrodinger equation; Equations of motion – Schrodinger picture, Heisenberg picture, interaction picture.

Theory of harmonic oscillator: Matrix formulation – creation and annihilation operators; Energy values; Matrix representation in |n> basis; Representation in the coordinate basis; Planck's law; Oscillator in higher dimensions.

Symmetry and conservation laws: Symmetry transformations – basic concepts, examples; Translation in space; Translation of time; Rotation in space; Space inversion; Time reversal.

Angular momentum: Orbital angular momentum - eigen values and eigen functions of L^2 and L_z; Angular momentum operators – commutation relations, eigen values and eigen functions; Representations of the angular momentum operators.

Spin: Idea of spin – Bosons, Fermions; Spin one-half – eigen functions, Pauli matrices; Total Hilbert space for spin-half particles; Addition of angular momenta; Clebsch-Gordan coefficients – computaion, recursion relations, construction procedure; Identical particles - symmetrisation postulate, Pauli exclusion principle, normalization of states.

One-electron atom: Schrodinger equation; Energy levels, Eigen functions and bound states, Expectation values and virial theorem; Solution in parabolic coordinates; Special hydrogenic atom (brief description) – positronium, muonium, anti-hydrogen, Rydberg atoms.

Two-electron atoms: Schrodinger equation for two-electron atoms – para and ortho states; Spin wave function – role of Pauli exclusion principle; Independent particle model; Bound state energies; Resonances.

Approximate methods for bound states: Variational method - Rayleigh-Ritz variational principle, applications (one dimensional harmonic oscillator, hydrogen atom, helium atom); Time-independent perturbation theory - Basic concepts; Derivation (up to the second order correction to the energy values and wave functions), applications (anharmonic oscillator; normal helium atom, ground state of hydrogen and Stark effect).

Relativistic quantum mechanics: Klein-Gordon equation – plane wave solution, interpretation of K-G equation; Dirac equation – covariant form, charged particle in electromagnetic field, equation of continuity, plane wave solution; Dirac hole theory; Spin of the Dirac particle.

Outcomes:

- Able to execute the stress state and stresses analysis Topic of Work: The stresses state analysis
- Able to solve a problem of strain analysis Topic of Work: The strain state analysis
- Able to use the numerical methods for the problem of the theory of elasticity in practice
- Able to use theory for solution of practice problem of stress and strain analysis.

Text Books:

1. Bransden B. H., and Joachain, C. J., Quantum Mechanics, Pearson.
2. Physics of Atoms and Molecules, *Pearson Education*.
3. Das A., Lectures on Quantum Mechanics, *Hindusthan Book Agency, New Delhi* (2003).

Reference books:

1. Cohen-Tannoudji C.,Diu B, and Laloe F., Quantum Mechanics Vol. 1, *Wiley- Interscience publication*.
2. Griffiths D. J., Introduction to Quantum Mechanics, *Pearson*.
3. Schiff L. I., Quantum Mechanics, *McGraw-Hill, New York*.

MSCMATHMJE313: THEORY OF ELASTICITY I

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- To analyse plane stress and plane strain problems
- To solve differential equations of equilibrium in terms of stresses
- To know the basic equations for bending of plates, Navier's and Levy solutions for rectangular plates
- To solve Eulevs equation by Ritz, Galerkin and Rantorovich method

Syllabus Contents

Motion of Deformable Bodies: Lagrangian and Eulerian descriptions, Material derivative, Conservation of mass, The continuity equation, Momentum principles, Equation of motion. Energy balance.

Constitutive Equations: Ideal materials, classical elasticity, Generalised Hooke's law. Isotropy. Elastic Moduli.

Linearised Elasticity: Equations of motion and Equilibrium in terms of Displacement components. Beltrami-Michell compatability equations, Strain energy density functions, Saint-Venant's principle, Boundary value problems of Static and dynamic Elasticity. Uniqueness of Solutions.

Two-Dimensional problems: Plane stress. Generalized plane stress, Airy stress function. General solution of bi-harmonic equation. Stresses and displacements in terms of complex potentials. Simple problems. Stress function approach to problems of plane stress.

Waves: Propagation of waves in an isotropic elastic solid medium. Waves of dilation and distortion. Plane waves. Elastic surface waves such as Rayleigh and Love waves.

Outcomes:

- Able to solve plane stress and plane strain problems in polar co-ordinates
- Able to measure pressure on the surface of a Semi-infinite body.
- Have knowledge about cylindrical bending of uniformly loaded plates
- The idea of solving Eulevs equation by several methods

References:

1. Love, A.E.H., A Treatise on the Mathematical Theory of Elasticity, Dover.
2. Sokolnikoff, I.S., Mathematical Theory of Elasticity, McGraw Hill, 1956.
3. Chung, T.J., Continuum Machanics, Prentice Hall,1988
4. Fung, Y.C., Foundations of Solid Mechanics.
5. Spencer, A.J.M., Continuum Mechanics, Longma, 1980.

SEMESTER-IV

MSCMATHC401: GRAPH THEORY

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objectives:

- To familiarize with the concept of different types of graphs and its components.
- To discuss the difference between walk and path, cycles and circuits, Adjacency matrix and Incidence matrix etc.
- To study the behavior of different types of graphs such as Eulerian, Hamiltonion, K-connected etc.
- To give an idea of DFS, BFS, shortest path problem, Chinese postman problem etc.

Syllabus Contents

Basic concepts: Elements of graph theory, Vertex, Degrees, Walks, Paths, Trails, Cycles, Circuits, Subgraphs, Induced subgraphs, Cliques, Components, Adjacency matrices, Incidence matrices, Isomorphism.

Graphs with special properties: Completes graphs, Bipartite graphs, Connected graphs, K-connected graphs, Edge-connectivity, Cut-vertices, Cut-edges, Eulerian Trails, Eulerian Circuits, Eulerian Graphs, characterization, Hamiltonian (Spanning) cycles, Hamiltonian graphs: Necessary conditions, sufficient conditions, Hamiltonian closure, Travelling salesman problem.

Trees: Basic properties, Distance, radius and centre, Diameter, Rooted trees, Binary trees, Binary Search tress, Cayley's formula for counting number trees, spanning trees of a connected graph, Depth first search (DFS) and Breadth first search (BFS) algorithms, Minimal spanning tree, Shortest path problem, Kruskal's algorithm, Prim's algorithm, Dijkstra's algorithm, Chinese Postman Problem.

Coloring of Graphs: Vertex coloring, proper coloring, k-colorable graphs, chromatic number, upper bounds, Cartesian product of graphs, Structure of k-chromatic graphs, Mycielski's Construction, Color-critical graphs, Chromatic Polynomial, Clique number, Independent (Stable) set of vertices, Independence number, Clique covering, Clique covering number. Perfect graphs : Chordal graphs, Interval graphs, Transitive Orientation, Comparability graphs. Edge-coloring, Edge-chromatic number, Line Graphs.

Outcomes: After successful completion of the course the student will be able to

- Define different graphs and its components.
- Discuss different theorems related to graph theory and to use it in real life problems.
- Distinguished different graphs.
- Solve real life problem using this knowledge.

References:

1. West, D.B., Introduction to Graph Theory, Pearson.
2. Parthasarathi, K.R., Basic Graph Theory, Tata McGraw-Hill, 1994.
3. Foulds, L.R., Graph Theory Applications, Narosa pub., 1993.
4. Deo, N., graph Theory with Applications to Engineering and computer science, PHI, 1997.
5. Ore, O., Theory of Graphs, AMS Colloq. 38, Amer.Math.Soc., 1962

MSCMATHC402: INTEGRAL TRANSFORMS & INTEGRAL EQUATIONS

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 4** ✧**L - T –P : 4 - 0 - 0**

Objectives:

- To gain a facility with using the integral transforms,
- To recognize when, why, and how integral transforms are used.
- To apply ingetral transforms to Heat, Wave and Laplace equations.
- To identify and classify linear integral equations and their several solution methodologies

Syllabus Contents

Integral Transforms:

Fourier Transforms: Fourier integral theorem, Definition and properties of Fourier Transforms, Fourier Transforms of Derivatives, Fourier Transforms of some useful functions, Fourier sine and cosine transforms, Inversion formula of Fourier Transforms, Convolution Theorem, Parseval's relation, Application of Fourier transforms to Heat, Wave and Laplace equations.

Laplace Transforms: Definition and properties of Laplace transforms, sufficient conditions for the existence of Laplace Transform, Laplace Transform of some elementary functions, Laplace Transforms of the derivatives, , Initial and final value theorems, Convolution theorems, Inverse of Laplace Transform, Bromwich integral theorem, Application to Ordinary and Partial differential equations.

Integral Equations :
Linear integral equations of 1st and 2nd kinds-Fredholm and Volterra types, Relation between integral equations and initial boundary value problems.
Existence and uniqueness of continuous solutions of Fredholm and Volterra's integral equations of second kind, Solution by the method of successive approximations, Resolvent Kernel method, Iterated Kernel method.

Integral equations with degenerate kernels, Fredholm theorem, Fredholm's determinant, Fredholm alternatives, Eigenvalue and eigenfunction of integral equation and their simple properties.

Integral equations with symmetrical kernels, Properties of symmetric kernels, Hilbert-Schmidt theory of symmetrical kernels, Schmidt's solution of Fredholm's integral equations, Integral equations of convolution type and their solutions by Laplace transform.

Outcomes:

- Indentify the integral transforms techniques
- Able to apply integral transform techniques to differential equations
- Understand integral equations and their solution procedure.

References:

1. Sneddon, I.N., Fourier Transforms, McGraw-Hill Pub.
2. Sneddon, I.N., Use of Integral Transforms, McGraw-Hill Pub.
3. Andrews, L.C., Shivamoggi, B., Integral Transforms for Engineers, PHI.
4. Debnath, L., Bhatta,D., Integral Transforms and Their Applications.
5. Tricomi, F.G., Integral Equation, Interscience Publishers
6. Chakraborti, A., Applied Integral Equation, Vijay Nicole Imprints Pvt Ltd.
7. Lovit, W.V., Linear Integral Equations, Dover Publishers.
8. Stackgold I., Green's Functions and Boundary Value Problems, *John Wiley & Sons, New York* (1979).

MSCMATHC403: DIFFERENTIAL GEOMETRY

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 4**	✧**L - T –P : 4 - 0 - 0**

Objective
The primary objective of this course is to understand the notion of level sets, surfaces as solutions of equations, geometry of orientable surfaces, vector fields, Gauss map, geodesics, Weingarten maps, line integrals and parametrization of surfaces, areas, volumes and Gauss-Bonnet theorem.

Syllabus Contents

Curves in Space: Parametric representation of curves, Helix, Bertrand curves, Curvilinear co-ordinates in E_3, Tangent and first curvature vector, Frenet formulae for curves in space, Frenet formulae for curves in E_n, Instrinsic differentiation, Parallel vector fields, Geodesic.

Surfaces in space: Parametric representation of a surface, Tangent and Normal vector field on a surface, The first and second fundamental tensor, Geodesic curvature of a surface curve, The third fundamental form, Gaussian curvature, Isometry of surfaces, Developable surfaces, Weingarten formula, Equation of Gauss and Codazzi, Principle curvature, Normal curvature, Meusnier's theorem.

Outcomes

After studying this course the student will be able to

- Understand the concepts of graphs, level sets as solutions of smooth real valued functions vector fields and tangent space.
- Comfortably familiar with orientation, Gauss map, geodesic and parallel transport on oriented surfaces.
- Learn about linear self-adjoint Weingarten map and curvature of a plane curve with applications in geometry and physics.
- Know line integrals, be able to deal with differential forms and calculate arc length and curvature of surfaces.
- Deal with parametrization and be familiar with well-known surfaces as equations in multiple variables, able to find area and volumes.
- Study surfaces with boundary and be able to solve various problems and the Gauss-Bonnet theorem.

References:

1. Eisenhert, L.P., An introduction to Differential Geometry, Princeton University Press.
2. Sokolnikoff, I.S., Tensor Calculus and Application to Geometry and Mechanics.
3. Wilmore, T.T., An Introduction to Differential Geometry.
4. Spain, B., Differential Geometry.
5. Pressely, Andrew, Elementary differential Geometry.

Major Electives

MAJOR ELECTIVE III & MAJOR ELCTIVE IV

MSCMATHMJE401: ADVANCED COMPLEX ANALYSIS II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objective

This course is aimed to provide the theories for functions of a complex variable in the advanced level. It begins with the mean value property of a harmonic function. Poisson's integral formula and

Dirichlet's problem for a disc are discussed. The concept of doubly periodic functions is introduced with the example of Weierstrass elliptic function. Nevanlinna's theory of meromorphic functions is also introduced in details.

Syllabus Contents

Harmonic functions, Characterization of harmonic functions by mean value property, Poisson's integral formula, Dirichlet problem for a Disc.

Doubly periodic functions, Weierstrass Elliptic functions.

Meromorphic functions, Expansions, Definition of functions m(r,a), N(r,a) and T(r). Nevanlinna's first fundamental theorem, Cartan's identity and convexity theorems, Order of growth, Order of a Meromorphic function, Comparative growth of log M(r) and T(r), Nevanlinna's second fundamental theorem, Estimation of S(r) (statement only), Nevanlinna's theory of deficient values, Upper bound of the sum of deficiencies.

Outcomes

Upon successful completion, students will have the knowledge and skills to:

- Explain the mean value property of harmonic function.
- Explain the doubly periodic function.
- Demonstrate Nevanlinna's theory to meromorphic function.

References:

1. Conway, J. B., Functions of one complex variables, Second edition, Narosa Pub.
2. Sarason, D., Complex function theory, Hindustan book agency, Delhi, 1994.
3. Ahlfors, L.V., Complex analysis, McGraw Hill, 1979.
4. Rudin, W., Real and complex analysis, Mc Graw Hill, 1966.
5. Hille, E., Analytic function theory, Gonn and Co. 1959.
6. Titchmarsh, E.C., The Theory of Functions, Oxford University Press, London
7. Markusevich, A.I., Theory of Functions of A Complex Variable, Vol. I,II,III.
8. Copson, E.T., An Introduction to the Theory of Functions of a Complex Variable.
9. Kaplan, W., An Introduction to Analytic Functions.

MSCMATHMJE402: ADVANCED FUNCTIONAL ANALYSIS II

- **Full Marks: 50** — **CA+ESE Marks: 10+40**
- **Credit: 5** — **L - T –P : 4 - 1 - 0**

Objectives:

- To study the behavior of special types of abstract spaces such as C (X,R) and C (X,C) where X is a compact Hausdorff space.

- To state and prove the Stone- Weierstrass theorem in the above spaces and its utility..

- To introduce the approximation theory in normed linear spaces and select best approximation.
- To familiarize with the concepts of resolvent operator, spectral radius, compactness of spectrum etc.
- To give an idea about some important theorems in Banach algebra and spectrum theory such as spectral mapping theorem, Gelfand Neumark theotem etc.

Syllabus Contents

Stone- Weierstrass theorem in C (X,R) and C (X,C) where X is a compact Hausdorff space, Representation theorem for bounded linear functional on C[a,b], Ip ($1 \leq p < \infty$) and Lp [a,b], ($1 \leq p < \infty$), consequences of uniform boundedness principle, weak topology, weak* topology, Branch-Alaoglu theorem.

Approximation Theory in Normed Linear space, Best approximation, Uniqueness Criterion, Separable Hilbert Space.

Banach Algebra, Identity element, analytic property of resolvent Operator, Compactness of Spectrum, Spectral radius and Spectral mapping Theorem for polynomials, Gelfand Theory on representation of Banach Algebra, Gelfand Neumark Theorem.

Outcomes: After completion of the course the student will be able to
- State Stone- Weierstrass theorem in abstract spaces.
- Select best approximation in normed linear spaces and Seperable Hilbert spaces.
- Calculate spectrum and spectral radius of bounded linear operators..
- State and prove Spectral mapping theorem, Gelfand Neumark theotem etc.

References:

1. Rudin, W., Functional Analysis, TMG Publishing Co.Ltd., New Delhi, 1973
2. Schaffer, A.A.,Topological Vector Spaces, Springer, 2nd Edn., 1991
3. Bachman, G., Narici, L., Functional Analysis, Academic Press, 1966
4. Kreyszig, E., Introductory Functional Analysis with Applications, Wiley Eastern, 1989
5. Diestel, Application of Geometry of Banach Spaces
6. Narici & Beckerstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985
7. Simmons, G. F.,Introduction to topology and Modern Analysis, Mc Graw Hill, New York, 1963

MSCMATHMJE403: ALGEBRAIC TOPOLOGY

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:
- To introduce the notion of homotopy, groups with pointed spaces and covering spaces which is closely associated with the fundamental groups.
- To compute the fundamental group of wedge of circles, Klein bottle, adjunction of a disc and a path connected space.
- To familiarize with the concepts of homology groups. The tools of homology theory are applied to prove a few classical applications like fixed point theorems, invariance of dimension, Euler's

formula, etc.

Syllabus Contents

Geometric complexes and Polyhedra, Orientation of geometric complexes, Chains, Cycles, Boundaries and Homology groups, Example of homology groups, The structure of homology groups, Euler-Poincaré theorem, Pseudomanifolds and the homology groups of S^n.

Simplical approximation, Induced homomorphisms on the homology groups, Brouwer Fixed Point theorem and related results.

Outcomes: After completing this course a student will be able to

- grasp the basics of Algebraic Topology.
- determine fundamental groups of some standard spaces like Euclidean spaces and spheres.
- understand proofs of some beautiful results such as Fundamental theorem of Algebra, Brower's fixed-point theorem.
- identify hyperplanes, simplexes and finite simplicial complexes as subsets of a Euclidean space.
- learn the use of homological algebra to associate simplicial homology groups with triangulable spaces and illustrate it by computing simplicial homology groups of some well-known compact polyhedral.
- understand the topological invariance of simplicial homology groups (up to homotopy).
- prove important applications of simplicial homology theory like invariance of dimension, Euler's formula, Brouwer's fixed point theorems, etc.

References:

1. Munkers, J.R., Topology, Pearson.
2. Croom, F.H., Basic Concepts of Algebraic Topology, Springer, NY, 1978.
3. Bredon, G.E., Topology and Geometry, Springer, India, 2005.
4. Spanier, E.H., Algebraic Topology, McGraw Hill, 1966.
5. Hatcher, A., Algebraic Topology, CUP, 2003.
6. Dieudonné, J., A History of Algebraic and Differential Topology.

MSCMATHMJE404: DIFFERENTIAL GEOMETRY OF MANIFOLDS II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objectives

In this course Riemannian manifolds are introduced. Curvature tensor, sectional tensor and Schur's theorem are discussed. The notion of geodesics in a Riemannian manifold is also presented. Weingarten equation, generalized Gaus and Mainardi-Codazzi equation are discussed in details. Also Nijenhuis tensor is introduced.

Syllabus Contents

Riemannian manifolds. Riemannian connection. Curvature tensors. Sectional Curvature. Schur's Theorem. Geodesics in a Riemanninan maniford. Projective curvature tensor. Conformal curvature tensor.

Submanifolds and Hypersurfaces. Normals. Gauss' formulae. Weingarten equation. Lines of curvature, Generalized Gauss and Mainardi-Codazzi equation.

Almost Complex manifolds. Nijenhuis tensor. Contravariant and almost analysis vector fields. F-Connection.

Outcomes: After completing this course, a student will be able to understand

- Riemannian geometry, Riemannian manifold
- Projective and Algebraic Geometry.
- Mathematical Physics, Relativity, Cosmology and Standard Models.

References:

1. Mishra, R. S., A course in tensor with applications to Riemannian Geometry, Pothishala Pub.
2. Mishra, R. S., Structures on a differentiable manifold and their applications, Chandrama Prakashan, Allahabad, 1984.
3. Sinha, B. B., An Introduction to Modern Differential Geometry, Kalyani Publishers, New Delhi,
4. Yano, K. and Kon, M., Structures of Manifolds, World Scientific Publishing Co. Pvt. Ltd., 1984
5. De, U.C., Shaikh, A. A., Differential Geometry of Manifolds, Narosa Publishing House Pvt. Ltd.

MSCMATHMJE405: SEMIGROUP THEORY

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- To familiarize with the concepts of semigroups and its sub systems.
- To study the behavior of different types of semigroups such as Completely regular semigroups, completely simple etc.
- To introduce simple semigroups, inverse semigroups and study their basic properties.

Syllabus Contents

B5: Semigroup Theory

Introduction: Basic definitions, Monogenic semigroups, Periodic semigroups, Ordered sets, Semilattices, Bands, Binary relations, Equivalences, Congruences, Ideals and Rees congruences, Green's equivalence relations, Regular semi groups.

Completely regular semigroups: Characteriozation of completely regular semigroups as union of groups, Semilattices of Groups, Clifford semigroups, Orthodox semigroups.

Simple and 0-simple semigroups, Completely simple, Completely 0-simple semigroups, Rees' theorem.

Inverse semigroups: Definitions and Elementary properties, Congruences on inverse semigroups, Fundamental inverse semi groups.

Outcomes: After completion of the course the student will be able to

- Define semigroups and its sub systems.
- Correlate semigroups with groups.
- Give an idea about different types of semigroups such as completely regular, simple, inverse semigroups.

References:

1. Howie, J. M., Fundamentals of Semigroup Theory, Clarendon, Oxford, 1995.
2. Howie, J. M., An introduction to semigroup theory, Academic Press, London, 1976.
3. Petrich, M, and Reilly, N. R., Completely Regular Semigroups, John Wiley & Sons.
4. Petrich, M., Structure of regular semigroups, Univ. de Montpellier, 1977.

MSCMATHMJE406: OPERATOR THEORY II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objectives:

- To familiarize with the concept of self adjoint operators, Normal operators, unbounded linear operators etc.
- To discuss the properties of various operators such as positive operators, projection operators etc.
- To study the behavior of spectrum theory in self adjoint linear operators.
- To state different theorems related to the above concepts and to use the same in real life problems, higher mathematics.

Syllabus Contents

Self-adjoint operators: Spectral properties of bounded self adjoint linear operators on a complex Hilbert space, Positive operators, Square root of a positive operator, Projection operators, Spectral family of a bounded self adjoint linear operator and its properties, Spectral theorem for a bounded self adjoint linear operator.

Normal Operators: Spectral properties for bounded normal operators, Spectral theorem for bounded normal operators.

Unbounded linear operators in Hilbert space: Hellinger-Toeplitz theorem, Symmetric and selfadjoint operators, Closed linear operators, Spectrum of an unbounded selfadjoint operator linear operator, Cayley transformation of an operator, Spectral theorem for unitary and selfadjoint operators, Multiplication operator and differentiation operator, Application to Quantum Mechanics.

Outcomes: After successful completion of the course the will able to

- Define different special types of operators such as Positive operators, Square root of a positive operator, Projection operators etc.

- Determine spectral family of different types of operators.

- Test the behavior of an unbounded linear operators.
- Use unitary and self adjoint operators, Multiplication operators, differentiation operators in the application of Quantum Mechaniques.

References:

1. Kreyszig, E., Introductory Functional Analysis with Appliactions, John Wiley and Sons.
2. Bachman, G., and Narici, L., Functional Analysis, Dover Publications.
3. Dunford, N., and Schwarts, J.T., Linear Operators-3, John Willey and Sons.
4. Halmos, P.R., Introduction to Hilbert Space and the theory of Spectral Multiplicity.

MSCMATHMJE407: BIOMATHEMATICS II

- **Full Marks: 50** — **CA+ESE Marks: 10+40**
- **Credit: 5** — **L - T –P : 4 - 1 - 0**

Objectives:

- To impart knowledge about basic equation for an n-compartment system
- To know the importance of studies on the mechanics of blood vessels
- To have knowledge of constituents of bloods and Mechanical properties of blood.
- To study Constitutive equations for blood vessels and equations of motion for the vascular wall.

Syllabus Contents

Some Mathematical Aspects of Oscillations of the Biological System

Introduction; Biological Clock; Model for the circadian oscillator. Mathematical models in Pharmacokinetics- Compartmental Analysis Technique. Two-compartment model- Clinical Bro msulphalein Test.

Basic equation for an n-compartment system. Distribution of drugs in n- compartment model for (i) given initial dose, (ii) repeated medication (iii) constant rate of infusion and (iv) truncated infusion.

Compartment model for diabetes mellitus.

Stochastic compartment models. Drug action. Some general principles for real biological oscillation.

Arterial Biomechanics

Importance of studies on the mechanics of blood vessels. Structure and functions of blood vessels; Mechanical properties.

Viscoelasticity; Linear discrete viscoelastic (spring-dashpot) models: Maxwell Fluid, Kelvin Solid, Kelvin Chains and Maxwell models. Creep Compliances, Relaxation Modulus. Hereditary Integral, Stieltjes Integrals.

Constituents of bloods, Structure and functions of the constituents of blood. Mechanical properties of blood. Equations of motion applicable to blood flow. Non-Newtonian fluids- Power law, Bingham Plastic, Herschel- Bulkley and Casson fluids. Steady non- Newtonian fluid flow in a right circular tube.Fahraeus-Lindqvist effect. Pulsatile flow in both rigid and elastic tubes. Blood flow through arteries with mild stenosis.

Large deformation theory, various forms of strain energy functions. The base vectors and metric tensors; Green’s deformation and Lagrangian strain tensor. Cylindrical model; Constitutive equations for blood vessels; equations of motion for the vascular wall.

Cranial Biomechanics

Importance of studying head-injury problems. Structure and different components of human head. Mechanical properties of the different components of head.

Geometrical shape of head. Hypotheses on brain damage.

Head injury mechanics- different types of head injury. Formulation of the problems: (i) when head is subjected to an impact. (ii) when head is subjected to rotational acceleration.

Outcomes:

- Able to identify basic equation for an n-compartment system
- Understand the importance of studies on the mechanics of blood vessels
- Have the knowledge of Geometrical shape of head and Hypotheses on brain damage.

References:

1. Kapur, J. N., Mathematical Models in Biology and Medicine, East West Press Pvt. Ltd (1985)
2. MacDonald, D. A., Blood Flow in Arteries, the Williams and Wilkins Company, Baltimore.
3. Fung, Y.C., Biomechanics of Soft Biological Tissues, Springer Verlag.
4. Habermann, R., Mathematical Models, Prentice Hall.
5. Poole, R. W., An Introduction to Quantitative Ecology, McGraw- Hill.
6. Pielou, E. C., An Introduction to Mathematical Ecology, Wiley, New York.
7. Rosen, R., Foundation of Mathematical Biology (Vol I & II), Academic Press.

MSCMATHMJE408: COMPUTATINAL FLUID DYNAMICS II

✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**

✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- To understand Conservation principles of fluid dynamics
- To study Boundary-Layer equations.
- To identify the applications of simple turbulence modelling.

Conservation principles of fluid dynamics, Basic Equations of viscous and inviscid flow. Basic equation in conservation from, Associated typical boundary

Condition for Euler and N-S equations, Lax-Wendorf and McCormack schemes for 2-D unsteady Euler equartion. Grid generation using elliptic partial differential equations. Boundary-Layer equations. Incompressible viscous flow field computation. Stream function vorticity and MAC method. Turbulance modeling, Viscous compressible flow computation based on RANS using simple turbulence modeling.

Outcomes:

- Able to identify Conservation principles of fluid dynamics
- Understand Stream function vorticity and MAC method

- Can compute Incompressible viscous flow field.

References:

1. Niyogi, P., Chakraborty, S. K. and Laha, M. K., Introduction to Computational Fluid Dynamics, Pearson.
2. Fletcher, C. A. J., Computational Techniques for Fluid Dynamices, Vol-1 and Vol-II, Springer.
3. Peyret, R., and Taylor, T. D., Computational Methods for Fluid Flow, Springer 1983.
4. Thompson, J.F., Warsi, Z.U.A. and C.W. Martin, C.W., Numerical Grid Generation, Foundation and Applications, North Holland 1985
5. Landau, L. D., Lifshitz, E. M., Fluid Mechanics, Trans, Pergamon Press 1989
6. Schlichting, H., Gersten, K., Boundary – Layer Theory, 8th Ed., Springer 2000

MSCMATHMJE409: FLUID MECHANICS II

✧ Full Marks: 50 **✧CA+ESE Marks: 10+40**

✧ Credit: 5 **✧L - T –P : 4 - 1 - 0**

Objectives:

- To study basic thermodynamics of compressible fluids
- To analyse characteristics and their use for solution of plane irrotational problem
- To impart knowledge of steady linearised subsonic and supersonic flows
- To know the motion due to a two dimensional source and vortex.

Syllabus Contents

Basic Thermodynamics of compressible fluids:
Field equation of fluid motion, crocco-vazsonyl equation. Propagation of small disturbances in a gas. Dynamics similarity of two flows. Plane rotational and irrotational motion with supersonic velocity. Steady flow through a De Level nozzle. Normal and oblique shock wave shock polar diagram.

Characteristics and their use for solution of plane irrotational problem. Prandtl-Mayer flow past a convex corner.

Steady linearised subsonic and supersonic flows. Prandtl-Glauert transformation. Flow along a wavy boundary. Flow past a slight corner. Jangen-rayleigh method of approximation. Ackeret's formula.

Lagendre and molenbroek transformations Chaplygin's equation for stream function. Solution of Chaplygin's equation. Subsonic gas jet problem, Limiting line. Motion due to a two dimensional source and vortex. Karman-Tsien approximation. Transonic vflow. Euler's_tricomi equation and its fundamental solution. Hypersonic flow.

Outcomes:

- Able to identify basic thermodynamics of compressible fluids

- Able to solve plane irrotational problem
- Able to solve Chaplygin’s equation and subsonic gas jet problem,

Reference:

1. Thompson, P. A.,Compressible fluid dynamics.
2. Shaproo, A. H., Compressible fluid flow.
3. Lipman, B., Aspects of subsonic and transonic flows.
4. Niyogi, P., Inviscid gas dynamics, Mcmillan, 1975 (India)
5. Oswatitsch, K., Gas dynamics.

MSCMATHMJE410: MECHANICS OF VISCOUS FLUID AND BOUNDARY LAYER THEORY II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

II

Objectives:

- To know the concept of boundary layer when the Reynolds number is moderately large
- To identify the Blasius equation for steady two-dimensional motions
- To impart knowledge about the Boundary layer for two-dimensional jet and the problem of steady three-dimensional jets.
- To study the unsteady motion of oscillatory cylinder and deduction of the oscillatory motion of a piston.

Syllabus Contents

Fundamental concept of boundary layer when the Reynolds number is moderately large. Prandtl’s equation of the boundary layer. expressions of displacement thickness and momentum thickness of the boundary layer. Vorticity and stress components within the boundary layer in two dimensional motions. Separation from boundary layer from an obstacle.

Blasius equation for steady two dimensional motions past a flat plate and its solution in the form of an infinite series. Boundary layer for two dimensional steady converging radial flow between two non parallel wall. Boundary layer for two dimension jet. Flow symmetrical about a free stream lines. Problem of steady three dimensional jet. Karman’s Integral equation of the boundary layer; interpretation of its term. Alternative form of integral equation in terms of displacement, thickness and momentum thickness. Application of karman’s integral equation in the study of the approximate solution of steady two dimensional flow past a flat plate and comparison with the corresponding exact solutions calculations of frictional resistance on both side of the plate and checking of errors. Application of this method by assuming liner, quadratic, cubic, and biquadratic distribution of velocity. Lamb’s Trigonometric solution. Mises’ Transformation of boundary layer equation into an equation of the conduction of heat with variable coefficient of conduction.

Non steady boundary layer, method of successive approximation and its application in the case of a flat plate impulsively set in motion. Unsteady motion of oscillatory cylinder and deduction of oscillatory motion of a piston.

Outcomes:

- Expose the concept of boundary layer
- Knowledge about boundary layer for two-dimensional jet
- Have the idea of transformation of the boundary layer equation into an equation of the conduction of heat
- Able to deduce the oscillatory motion of a piston.

References:

1. Viscous flow theory, Vol-I – S.I. Pai
2. Hydrodynamics- H. Lamb
3. New method in laminar boundary layer theory- D. Meksyn
4. Elementary treatise on the hydrodynamics and sound- A.B. Basset
5. Modern development in fluid dynamics- S. Goldstein
6. Boundary Layer theory- H. Schlichting
7. Laminar boundary layers- L. Rosenhead

MSCMATHMJE411: OPERATIONS RESEARCH II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objectives:

- To develop operational research models of the real system.
- To understand the mathematical tools that are needed to solve optimization problems.
- To formulate and solve problems as networks
- To analyse and solve replacement and maintenance models
- To provide necessary mathematical support to tackle real-life problems of queue theory.

Syllabus Contents

Network Flow: Max-flow min cut theorem, generalized max flow min-cut theorem, linear programming interpretation of Max-flow min cut theorem, minimum cost flows, Min flow max-cut theorem.

Goal Programming: Introduction, Difference between LP and GP approach, graphical solution method of Goal programming, Modified simplex method of Goal programming.

Dynamic Programming: Characteristic of dynamic programming problems, Bellman's principle of optimality (Mathematical formulation), Single additive constraint, multiplicative separable return, Single additive constraint, additively separable return, Single multiplicative constraint, additively separable return, Shortest route problems. Multistage decision process- Forward and Backwar recursive approach, Dynamic Programming approach for solving linear and non-linear programming problems, Applications.

Replacement and Maintenance Models: Introduction, Failure Mechanism of items, Replacement of items deteriorates with time, Replacement policy for equipments when value of money changes with constant rate during the period, Replacement of items that fail completely— individual replacement policy and group replacement policy, other replacement problems — staffing problem, equipment renewal problem.

Queuing Theory: Introduction, Features of Queuing systems, Queue disciplines, The Poisson process (Pure birth process), Arrival distribution theorem, Properties of Poisson process, Distribution of inter arrival times (exponential process), Markovian property of inter arrival times, Pure death process (Distribution of departures), Derivation of service time distribution, Analogy of exponential service times with Poisson arrivals, Kendals notations, Solution of Queuing models: {(M/M/1):($\infty|FCFS)$}, {(M/M/1):($n|FCFS)$}, {(M/M/s):($\infty|FCFS)$}, {(M/M/s):($n|FCFS)$}.

Outcomes:

- Able to acquire skills in handling replacement and maintenance models
- Able to apply basic techniques to analyze in networking
- Understand and characterize the phenomena of dynamic programming problems
- Expose the basic characteristic features of a queuing system and acquire skills in analyzing queuing models.

References:

1. Hadley, G., Nonlinear and Dynamic Programming, Pearson.
2. Rao, S.S., Optimization Theory and Application, Wiley Eastern.
3. Sarup, K., Gupta, P.K., and Mohan, Man, Operations Research, Sultan Chand & Sons.
4. Sharma, J.K., Opeartions Research, Mcmillan, India.
5. Sharma, S.D., Operation Research, Kedarnath & Ramnath, Meerut.
6. Joshi, M.C., and Moudgalya, K.M., Optimization theory and Practice, Narosa Pub.
7. Bector, C.R., Chandra, S., and Dutta, J., Principles of Optimization Therory, Narosa Pub.

MSCMATHMJE412: QUANTUM MECHANICS II

- ✧ **Full Marks: 50** ✧**CA+ESE Marks: 10+40**
- ✧ **Credit: 5** ✧**L - T –P : 4 - 1 - 0**

Objectives:

- To calculate the approximate values of energy for various systems.
- To learn the methods of finding transition probability for absorption and emission.
- To study the scattering phenomena.
- To appreciate the beauty of quantum mechanics in the form of the Born approximation and its

validity.

- To study the wave functions of a system of identical particles.

Syllabus Contents

Scattering theory: Basic concepts – types of scattering, channels, thresholds, cross sections; Classical description – equation of trajectory, cross sections, Hard-sphere scattering, Rutherford scattering; Quantum description – cross sections, Laboratory frame and centre of mass frame, optical theorem.

Method of partial waves for potential scattering: Description of the method; Phase shift; Convergence of partial wave series; Zero-energy scattering - scattering length, S-matrix, K-matrix, T-matrix; Relation between phase shift and potential; relation to cross sections – optical theorem.

Integral equation of potential scattering: Description of the method; Lippmann-Schwinger equation; Integral representation of scattering amplitude.

Scattering by Coulomb potential: Scattering state solution in parabolic coordinates; Cross sections; Modified Coulomb potentials.

Approximate methods for potential scattering: WKB method - connection formula, validity, α -emission, bound state in a potential well; Born series – first and second Born amplitudes, validity of FBA; eikonal approximation – description, scattering amplitude, cross sections.

Variational methods in potential scattering: Differential form – Kohn variational method, inverse Kohn variational method, Hulhen variational method, Kohn-Hulthen variational method; Schwinger variational principle – scattering amplitude, phase shift, bound principle.

Quantum statistics: Fundamental assumption; Most probable configuration; Maxwell-Boltzmann distribution, Fermi-Dirac distribution and Bose-Einstein distribution; Black body spectrum.

Elements of field quantization: Classical field equations – Lagrangian and Hamiltonian form; Quantization of field - Schrodinger equation; Relativistic fields - Klein-Gordon field, Dirac field; Quantization of electromagnetic field.

Outcomes:

- Able to calculate the ground state and excited state energies of various real-life systems.
- Students will be knowing about Einstein's coefficients and relating them to lasers.
- Have knowledge about scattering in two different frames and can easily calculate scattering amplitude and scattering cross-section.
- can write total energy and wave function as a slater determinant for a system of identical fermions.

Text books:

1. Bransden B. H., and Joachain, C. J., Quantum Mechanics, Pearson.
2. Bransden, Physics of Atoms and Molecules, *Pearson*.
3. Das A., Lectures on Quantum Mechanics, *Hindusthan Book Agency, New Delhi* (2003).

Reference books:

1. Cohen-Tannoudji C., Diu B, and Laloe F., Quantum Mechanics Vol. 1, *Wiley- Interscience publication* (1977).
2. Griffiths D. J., Introduction to Quantum Mechanics, *Pearson.*
3. Schiff L. I., Quantum Mechanics, *McGraw-Hill, New York* (1968).

MSCMATHMJE413: THEORY OF ELASTICITY II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

MSCMATHMJE413: THEORY OF ELASTICITY II

✧ **Full Marks: 50**	✧**CA+ESE Marks: 10+40**
✧ **Credit: 5**	✧**L - T –P : 4 - 1 - 0**

Objectives:

- To analyse plane stress and plane strain problems
- To solve differential equations of equilibrium in terms of stresses
- To know the basic equations for bending of plates, Navier's and Levy solutions for rectangular plates
- To solve Eulevs equation by Ritz, Galerkin and Rantorovich method.

Syllabus Contents

Solution by means of functions of a complex variable: Plane stress and plane strain problems. Solution of plane stress and plane strain problems in polar co-ordinates. General solution for an infinite plate with circular hole. An infinite plate under the action of concentrated forces and moments.

Three dimensional problems: Beam stretched by its own weight. Solution of differential equations of equilibrium in terms of stresses \. Stress function. Reduction of Lame and Beltrami equations to biharmonic equations. Relvin and Boussinesq-Papkovich solution. Pressure on the surface of a Semi-infinte body.

Theory of thin plates: Basic equations for bending of plates. Boundary conditions. Navier's and Levy solutions for rectangular plates. Circular plate. Cylindrical ben ding of uniformly loaded plates.

Variational methods: Theorems of minimum potential energy. Theorems of minimum supplementary energy. Uniqueness of solutions. Reciprocal theorem of Betti and Rayleigh-applications. Solution of Eulevs equation by Ritz, Galerkin and Rantorovich method.

Outcomes:

- Able to solve plane stress and plane strain problems in polar co-ordinates

- Able to measure pressure on the surface of a Semi-infinite body.
- Have knowledge about cylindrical bending of uniformly loaded plates
- The idea of solving Eulevs equation by several methods.

References:

1. Love, A.E.H., A Treatise on the Mathematical Theory of Elasticity, Dover.
2. Sokolnikoff, I.S., Mathematical Theory of Elasticity, McGraw Hill, 1956.
3. Fung, Y.C., Foundations of Solid Mechanics.
4. Eringen, A.C., Elasto-dynamics.
5. Sada, A.S., Elasticity theory and Applications.
6. Chung, T.J., Continuum Machanics, Prentice Hall,1988.

MSCMATHC404: PROJECT WORK

✧ **Full Marks: 50** ✧**CA+ESE Marks: 30+20**

✧ **Credit: 2** ✧**L - T –P : 1 - 0 - 2**

Objectives:

- To give an idea about research work.
- To familiarize with literature review, reference and bibliography, APA style, data analysis etc.
- To develop skills of computer software and languages such as Linux, MATLAB etc.
- To develop communication and presentation skills such as Power point, Bimer Presentation etc.

Syllabus Contents

The project work will be performed on some advanced topics or review work of research papers. The marks distribution of project work is as follows: 30 marks allotted for written submission, 15 marks for seminar presentation and 5 marks allotted for viva-voce examination. The evaluation of project work of each student will be done by the concerned internal teacher/supervisor and one external examiner.

Outcomes: After completion of the course the student will be able to

- Acquire knowledge about literature review, data collection, data analysis, references etc,
- Discuss the possible research problems and its solving methods.
- Write a report to a particular topic.
- Present a paper using ICT.

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