SYLLABUS & PROGRAMME STRUCTURE

M.Sc.

in

Mathematics

(Choice Based Credit System)

(Effective from the Academic Session 2021-2022)

DEPARTMENT OF MATHEMATICS
MAHARAJA BIR BIKRAM UNIVERSITY
AGARTALA, TRIPURA: 799004

Maharaja Bir Bikram University

Agartala, Tripura

Department of Mathematics

Syllabus Structure of M. Sc. (P.G.) Course in MATHEMATICS

Credit Requirement: M.Sc. degree programme shall have a minimum specified credit requirement. For M. Sc in Mathematics a student shall have to earn 64 (sixty four) credits from Department of Mathematics. He/she has to earn 10 (ten) credits compulsorily from other Departments. That is altogether a Student shall have to earn 74 (seventy four) credits to complete the M. Sc in Mathematics.

Credit from Department of Mathematics	**64**
Compulsory credit from other Departments	**8**
Compulsory credit from Communication Skills in English	**2**
Credit that a student has to earn to obtain M Sc in Mathematics	**74** (64 from Department of Mathematics + 10 Compulsory credits from other Departments)

**** Each course in M. Sc in Mathematics shall have 4 Credit and 100 Marks.**

Table – 1: ***Core Courses***

Sl. No.	Course Code	Course Title	Credit	Full Marks (Internal + End Term)
1	MATH-101C	Abstract Algebra	4	100 (30+70)
2	MATH-102C	Real Analysis and Measure Theory	4	100 (30+70)
3	MATH-103C	Classical Mechanics	4	100 (30+70)
4	MATH-104C	Ordinary and Partial Differential Equations	4	100 (30+70)
5	MATH-201C	Complex Analysis	4	100 (30+70)
6	MATH-202C	Linear Algebra	4	100 (30+70)
7	MATH-203C	Continuum Mechanics	4	100 (30+70)
8	MATH-204C	Functional Analysis	4	100 (30+70)
9	MATH-301C	Topology	4	100 (30+70)
10	MATH-302C	Numerical Analysis with Computer Applications -I	4	100 (30+70) [End Term: 70 marks (Theory: 50 + Practical: 20)]
11	MATH-303C	Graph Theory	4	100 (30+70)
12	MATH-401C	Integral Transforms and Integral Equations	4	100 (30+70)
13	MATH-402C	Numerical Analysis with Computer Applications -II	4	100 (30+70) [End Term: 70 (Theory: 40 + Practical: 30)]
		Total	**52**	**1300**

Table – 2: ***Discipline Specific Elective Courses offered by the department of Mathematics for Third (3rd) Semester***

Sl. No.	Course Code	Course Title	Credit	Full marks
1	MATH-301E	Probability and Statistics	4	100 (30+70)
2	MATH-302E	Operations Research	4	100 (30+70)
3	MATH-303E	Fuzzy Set Theory and Applications	4	100 (30+70)
4	MATH-304E	Nonlinear Dynamics	4	100 (30+70)
5	MATH-305E	Mathematical Elasticity	4	100 (30+70)
6	MATH-306E	Fluid Dynamics	4	100 (30+70)
7	MATH-307E	Vedic Mathematics	4	100 (30+70)

Table – 3: ***Discipline Specific Elective Courses offered by the department of Mathematics for Fourth (4th) Semester***

Sl. No.	Course Code	Course Title	Credit	Full marks
1	MATH-401E	Discrete Mathematics	4	100 (30+70)
2	MATH-402E	Advanced Operations Research	4	100 (30+70)
3	MATH-403E	Fuzzy Topology	4	100 (30+70)
4	MATH-404E	Mathematical Biology	4	100 (30+70)
5	MATH-405E	Advanced Mathematical Elasticity	4	100 (30+70)
6	MATH-406E	Advanced Fluid Dynamics	4	100 (30+70)
7	MATH-407E	Project Work	4	100 (30+70)

Table – 4: ***Elective Course for the students of other Departments offered by the Department of Mathematics***

	Course Code	Course Title	Credit	Full marks
1	MATH-205OE	Mathematics for Social Sciences	4	100 (30+70)

Table – 5: ***The course as mentioned below to be taken by a FIRST Semester student of the Department of Mathematics as a Compulsory Course from other Departments:***

Sl. No.	Course Code	Course Title	Credit	Full marks
1	MATH-105COE	Foundation Course of Advanced Computer Skills	4	100 (30+70) [End Term: 70 (Theory: 50, Practical: 20)]

Table – 6: ***One of the courses as mentioned in Table-6 to be taken by a SECOND Semester student of the Department of Mathematics as a Compulsory Open Elective Course from other Departments***

Sl.No.	Course Code	Course Title	Credit	Full marks
1	NSS-201OE	National Service Scheme	4	100 (30+70) [End Term: 70 (Theory: 40, Practical: 30)]
2	MATH-206OE	SWAYAM/MOOCs Courses	4	100 (30+70)
3	. * To be decided by the other departments.	Courses offered by the other departments	4	100 (30+70)

Courses offered by the Department of Mathematics Semester wise:

Semester I:

Sl. No.	Type of Course: Course Title	Credit	Full marks
1	**Core Course:** Abstract Algebra	4	100 (30+70)
2	**Core Course:** Real Analysis and Measure Theory	4	100 (30+70)
3	**Core Course:** Classical Mechanics	4	100 (30+70)
4	**Core Course:** Ordinary and Partial Differential Equations	4	100 (30+70)
5	**Compulsory Open Elective Course from other Departments:** Foundation Course of Advanced Computer Skills	4	100 (30+70)
6	**Compulsory Course from other Department:** Communication Skills in English	2	100 (30+70)

	Total	**22**	**600**

Semester II:

Sl. No.	Type of Course: Course Title	Credit	Full marks
1	**Core Course:** Complex Analysis	4	100 (30+70)
2	**Core Course:** Linear Algebra	4	100 (30+70)
3	**Core Course:** Continuum Mechanics	4	100 (30+70)
4	**Core Course:** Functional Analysis	4	100 (30+70)
5	**Compulsory Open Elective Course**: Courses offered by other Departments/NSS Unit/MOOCs	4	100 (30+70)
	Total	**20**	**500**

Semester III:

Sl. No.	Type of Course: Course Title	Credit	Full marks
1	**Core Course**: Topology	4	100 (30+70)
2	**Core Course**: Numerical Analysis with Computer Applications -I	4	100 (30+70) [End Term: 70 (Theory: 50 + Practical: 20)]
3	**Core Course**: Graph Theory	4	100 (30+70)
4	**Discipline SpecificElective Course**: One Elective Course from Table 2	4	100 (30+70)
	Total	**16**	**400**

Semester IV:

Sl. No.	Type of Course: Course Title	Credit	Full marks
1	**Core Course**: Integral Transforms and Integral Equations	4	100 (30+70)
2	**Core Course**: Numerical Analysis with Computer Applications -II	4	100 (30+70) [End Term: 70 marks (Theory: 40 + Practical: 30)]
3	**Discipline SpecificElective Course**: One Elective Course from Table 3	4	100 (30+70)
4	**Discipline SpecificElective Course**: One Elective Course from Table 3	4	100 (30+70)
	Total	**16**	**400**

Detailed Syllabus

Course Title: Abstract Algebra
Course Code: MATH-101C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *This course aims to provide a first approach to the subject of algebra, which is one of the basic pillars of modern mathematics. The focus of the abstract algebra course will be the study of certain structures called groups, rings, fields and some related structures. Applications of abstract algebra are increasingly important in certain areas, for example in communication theory, electrical engineering, computer science, and cryptography.*

UNIT-I: Quotient groups, Isomorphism Theorems, Cayley's Theorem, Generalised Cayley's Theorem, Cauchy's Theorem, Group Action, Sylow Theorems, and their applications. Normal and Subnormal series, Composition series, Solvable groups and nilpotent groups, Jordan-Holder theorem and its applications.

UNIT-II: Ideals and Homomorphism, Prime and Maximal Ideals, Quotient Field and Integral Domain, Polynomial and power series Rings. Divisibility Theory: Euclidean Domain, Principal Ideal Domain, Unique Factorization Domain, Gauss Theorem. Noetherian and Artinian Rings, Hilbert's Basis Theorem, Chen's Theorem.

UNIT-III: Left and Right Modules over a ring with identity, Cyclic Modules, Free Modules, Fundamental structure theorem for finitely generated modules over a PID and its application to finitely generated abelian groups.

UNIT-IV: Fields, Finite fields, Extension fields, algebraic and transcendental extension, separable and normal extensions, perfect fields, algebraically closed fields.

UNIT-V: Galois Group of automorphisms and Galois Theory, Solution of polynomial equations by radicals, Insolvability of the general equation of degree 5 (or more) by radicals.

** Any other advancement in this field may be incorporated.

References :

1. D. S. Dummit and R. M. Foote, Abstract Algebra, Second Edition, John Wiley & Sons. Inc., 1999.
2. Malik, Moderson, Sen, Fundamentals of Abstract Algebra, The McGraw Hill Companies Inc.
3. J. K. Goldhaber and G. Ehrlich, Algebra, The Macmillan Company, Collier-Macmillan Limited, London.
4. I. N. Herstein, Topics in Abstract Algebra, Wiley Eastern Limited.
5. T. W. Hungerford, Algebra, Springer.
6. V. K. Khanna and S. K. Bhambri, A course in Abstract Algebra, Vikas Publishing House Pvt. Ltd.

Course Title: Real Analysis and Measure Theory
Course Code: MATH-102C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *Real analysis is the fundamental concept of mathematics. Without proper understanding of real analysis it is quite difficult to advance in any field of mathematics. Real analysis is an area of analysis that studies concepts such as sequences and their limits, continuity, differentiation, integration and sequences of functions. By definition, real analysis focuses on the real numbers, often including positive and negative infinity to form the extended real line. In mathematical analysis, a* ***measure*** *on a set is a systematic way to assign a number to each suitable subset of that set, intuitively interpreted as its size. In this sense, a measure is a generalization of the concepts of length, area, and volume.*

UNIT-I: Definitions and examples of spaces like $R^n, C^n, l_n^p,\ l^p$. Open sphere, closed sphere (elements of point set theory), sequences, Cauchy sequences, Cantor intersection theorem, complete metric space, continuity and compactness, Baire Category theorem, equivalent metric , extension theorem , uniform continuity.

UNIT-II: Properties of functions of bounded variation. Total variation, Continuous function of bounded variation, Differentiation of a function of bounded variation, Function of bounded variation expressed as the difference of the increasing functions,Absolutely continuous function, Representation of an absolutely continuous function by an integral. Definitions and examples, integration and differentiation, the upper and lower Darboux - Stieltje's integrals.

UNIT-III: Measurable sets, Length of sets, Outer measure, Lebesgue outer measure, Properties of measurable sets, Borel sets and their measurability, Characterization of measurable sets, Regularity, Non-measurable sets.

UNIT-IV: Definition, examples and different properties of measurable functions, step function, operations on measurable functions, characteristic function, simple function, continuous function, sets of measure zero. Borel measurable functions, Convergence in measure, Sequence of measurable functions and their properties. Egoroff's Theorem, Lusin's Theorem. Almost uniform convergence.

UNIT-V: Lebesgue integration of single function, Lebesgue integral of a bounded function, Riemann integral, comparison of Riemann integral & Lebesgue integral.Properties of the Lebesgue integral for bounded measurable functions, Integral of non-negative measurable functions.

** Any other advancement in this field may be incorporated.

References:

1. W. Rudin , Principle of Mathematical Analysis, Mc Grow Hill 1976.
2. Rana, An Introduction to Measure and Integration, Narosa.
3. T. M. Apostole , Mathematical Analysis , Narosa pub. House 1985.
4. M. H. Potter and C. B. Morrey , A first course in Real analysis, Springer.
5. C. D. Aliprantis and O. Burkinshaw, Principles of Real analysis, 3rd Edition, Harcourt Asia Pte Ltd., 1998.
6. H. L. Royden, Real Analysis, 3rd Edition, MacMillan, New York and London, 1988.
7. P. R. Halmos, Measure Theory, Van Nostrand, New York, 1950.
8. A. N. Kolmogorov, Meassures, Lebesgue Integrals and Hillbert Space, Academic Press, New Yorkand London, 1961.
9. P. K. Jain and V. P. Gupta, Lebesgue Measure & Integration, New Age International Pvt. Ltd.

Course Title: Classical Mechanics

Course Code: MATH-103C

Full Marks: 100 (End Term: 70 + Internal: 30)

Credit: 4

Objectives: *Classical mechanics is a physical theory describing the motion of macroscopic objects, from projectiles to parts of machinery, and astronomical objects, such as spacecraft, planets, stars and galaxies. For objects governed by classical mechanics, if the present state is known, it is possible to predict how it will move in the future (determinism) and how it has moved in the past (reversibility). Classical mechanics provides extremely accurate results when studying large objects that are not extremely massive and speeds not approaching the speed of light. When the objects being examined have about the size of an atom diameter, it becomes necessary to introduce the other major sub-field of mechanics: quantum mechanics. To describe velocities that are not small compared to the speed of light, special relativity is needed.*

UNIT-I: Basic concepts, definitions and problems. *Conservative force:* Basic concepts, definitions, related theorems and problems. *Constraints:* Basic concepts, definitions and examples of systems with unilateral, bilateral, holonomic, non-holonomic, seleronmic, rhenomic, conservative, dissipative constraints and related problems. Degrees of freedom: Basic concepts, definitions and related problems. Generalized Coordinates, Virtual work, D'Alembert's principle and related problems.

UNIT-II: Lagrange's equation of first and second kind, Uniqueness of solution, Application of Lagrangians, Energy equation for conservative field, Cyclic or ignorable coordinates, Routhian, Liouville's class of Lagrangians. Problems related to all the topics. Hamiltonian, Hamilton's canonical equations, Hamilton's principle (general and modified), Derivation of Lagrange's equations of motion, Hamilton's equations of motion from Hamilton's principle, Principle of least action, Noether's theorem. Problems related to all the topics.

UNIT-III: Euler's dynamical equations, Rotating coordinate system, Foucault pendulum and torque free motion of a rigid body about a fixed point, Motion of a symmetrical top and theory of small vibrations. Problems related to all the topics.

UNIT-IV: Poisson's bracket, Poisson's identity, Jacobi-Poisson theorem. Hamilton Jacobi equations, Time dependent Hamilton-Jacobi equation and Jacobi's theorem, Lagrange brackets, Condition of canonical character of transformation in terms of Lagrange brackets and Poisson brackets, Invariance of Lagrange brackets and Poisson brackets under canonical transformations. Problems related to all the topics.

UNIT-V: Functional, Properties of functional, Linear and nonlinear functional, Optimal value, Euler-Lagrange equation in n-dimension, Extremum of a functional, Geodesic, Shortest distance between two points, The Barchistochorne problem and its solution, Applications of Barchistochorne problem.

** Any other advancement in this field may be incorporated.

References:

1. H. Goldstein, *Classical Mechanics.*
2. N. C. Rana *and* P. S. Jog, *Classical Mechanics.*
3. L. N. Hand *and* J. D. Finch, *Analytical Mechanics.*
4. AS. L. Loney, *Rigid Dynamics.*
5. Gupta, Kumar, Sharma, *Classical Mechanics.*
6. A. S. Gupta, *Calculus of Variations with Applications*

Course Title: Ordinary and Partial Differential Equations
Course Code: MATH-104C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In mathematics, a differential equation is an equation that relates one or more functions and their derivatives In applications, the functions generally represent physical quantities, the derivatives represent their rates of change, and the differential equation defines a relationship between the two. Such relations are common; therefore, differential equations play a prominent role in many disciplines including engineering, physics, economics, and biology.In mathematics, a partial differential equation (PDE) is an equation which imposes relations between the various partial derivatives of a multivariable function. Partial differential equations are ubiquitous in mathematically-oriented scientific fields, such as physics and engineering. For instance, they are foundational in the modern scientific understanding of sound, heat, diffusion, electrostatics, electrodynamics, fluid dynamics, elasticity, general relativity, and quantum mechanics.*

UNIT-I: Initial value problem of first order ODEs, Existence and Uniqueness of solutions of IVP, Singular solution, General theory of homogeneous and non homogeneous linear ODE, Variation of parameters,Sturn-Liouville Boundary Value Problem, Green’s Function. Ascoli-Arzoli theorem, Theorem on convergence of solution of IVP.

UNIT-II: Picard –Lindeloff theorem, Piano’s Existence Theorem, Systems of first order ODEs, Independence of the solution of linear differential equation, Wronskian and its properties, exact differential equation and equation of special form. Adjoint and self-adjoint equations.

UNIT-III: Series solution by the method of Frobenius, Hypergeometric equation and Hypergeometric functions, Legendre differential equation and Legendre polynomials, Bessel’s differential equation and Bessel’s function. Laguerre differential equation and Lagurre polynomial, Hermite differential equation and Hermite polynomial; recurrence relations, orthogonal properties.

UNIT-IV: Formation of partial differential equations, Pfaffian differential equations - Quasi-linear equations, Lagrange's method, Charpit's method, Solution of higher order partial differential equation with constant coefficients, Cauchy problem for first order partial differential equations.

UNIT-V: Classification of second order PDE's, Linear PDE with constant coefficients, reducible and irreducible equations. Different methods of solution. Second order PDE with variable coefficients. Characteristic curves of second order PDE. Reduction to canonical forms. D’Alembert’s solution of wave equation. Solutions of PDE of second order by the method of separation of variables. Boundary value problems, Dirichlet,s and Neumann’s interior and exterior problems uniqueness and continuous dependence of the solution on the boundary conditions.

** Any other advancement in this field may be incorporated.

References:

1. G. F. Simmons, Differential Equations with Applications and Historical Notes,(McGraw Hill, 1991).
2. Codington and Levison, Theory of Ordinary Differential equations, Tata McGrawHill3.
3. P. Hartman, Ordinary differential equations , John wiley and sons
4. W. T. Reid , Ordinary differential equations , John wiley and sons .
5. Ian Sneddon, Elements of Partial Differential Equations, Mcgraw Hill.
6. K. S. Rao, Introduction to partial differential equations (Prentice Hall of India, New Delhi, 2006).
7. W. E. Williams, Partial Differential Equations, Oxford Applied Mathematics and Computing Science Series.
8. I. G. Petrovsky, Lectures on Partial Differential Equations.

Course Title: Complex Analysis
Course Code: MATH-201C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *Complex analysis, traditionally known as the theory of functions of a complex variable, is the branch of mathematical analysis that investigates functions of complex numbers. It is useful in many branches of mathematics, including algebraic geometry, number theory, analytic combinatorics, applied mathematics; as well as in physics, including the branches of hydrodynamics, thermodynamics, and particularly quantum mechanics. By extension, use of complex analysis also has applications in engineering fields such as nuclear, aerospace, mechanical and electrical engineering*

UNIT-I: Cauchy-Riemann equations, Orthogonality of function arising out of analytic function, Harmonic functions, Power Series as an analytic function, Curves in complex plane, properties of complex line integrals, Cauchy-Goursat theorem, Consequence of simply connectivity, Winding number or Index of a curve, Cauchy integral formula, Morera's theorem, Cauchy inequality, Liouville's theorem, Maximum modulus theorem, Schwarz lemma, Fundamental theorem of algebra, Meromorphic function.

UNIT-II: Isolated and Non-isolated singularities, removable singularities, Poles, Isolated singularities at infinity, Meromorphic functions, essential singularities and Picard's theorem, Residue at a finite point, residue at the point at infinity, residue theorem, numbers of zeroes and poles, Rouche's theorem.

UNIT-III: Power series, Taylor series, Laurent series, Cauchy series, Open mapping theorem, Bi-linear transformation, Conformal mapping, Basic properties of Mobius maps, fixed points and Mobius maps, Triples to Triples under Mobius maps, The cross-ratio and its invariance property, Principles of symmetry and Mobius maps.

UNIT-IV: Integrals of type: $\int_{\alpha}^{2\pi+\alpha} R(cos\theta, sin\theta)d\theta$, $\int_{-\infty}^{\infty} f(x)dx$, $\int_{-\infty}^{\infty} g(x)cos(mx)dx$.
Singularities on the real axis, Integrals involving branch points, Estimation of sums, Contour integration.

UNIT-V: Direct analytic continuation, Monodromy theorem, poisson Integral formula, Analytic continuation via reflection, Infinite sumsand meromorphic functions, Infinite product of complex numbers, Infinite product of analytic functions, factorization of Entire functions, The Gamma function, The Zeta function, Jensen's theorem.

** Any other advancement in this field may be incorporated.

References:

1. J. B. Conway, Function of one complex variable, Narosa publication.
2. H. S. Kasana, Complex Variable, Prentic Hall of India.
3. S. Punnusamy, Functions of complex analysis, Narosa.
4. E. T. Copson, An introduction to theory of functions of complex variable, Oxford Clarendon Press, 1962.
5. T. M. Mac Robert, Functions of a Complex variables, Macmillan, 1962.
6. W. Rudin, Real and Complex Analysis, McGrawHill.
7. A. Gupta, Principles of Complex Analysis, Academic Publishers.

Course Title: Linear Algebra
Course Code: MATH-202C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives*: Linear algebra is central to almost all areas of mathematics. For instance, linear algebra is fundamental in modern presentations of geometry, including for defining basic objects such as lines, planes and rotations. Also, functional analysis, a branch of mathematical analysis, may be viewed as basically the application of linear algebra to spaces of functions. Linear algebra is also used in most sciences and fields of engineering, because it allows modeling many natural phenomena, and computing efficiently with such models.*

UNIT-I: Characteristic Values, Annihilating Polynomiall, Diagonalizable and Triangulable operators , Minimal polynomial, Invariant Subspaces, Simultaneous Triangulation; Simultaneous Diagonalization, Direct-Sum Decompositions, Invariant Direct Sums, The Primary Decomposition Theorem, T-conductors and related theorems.

UNIT-II: Cyclic Subspaces and Annihilators, Cyclic Decompositions and the Rational Form, The Jordan Form, Computation of Invariant Factors, Semi-Simple Operators, Rational canonical forms.

UNIT-III: Inner products, Inner Product spaces, Norms of vectors and matrices, Normed linear spaces, Induced norms, Transformation of matrices, adjoint of an operator, normal, unitary, Hermitian and skew-Hermitian operators, Linear Functionals and Adjoints, Unitary Operators, Normal Operators.

UNIT-IV: Forms on Inner Product Spaces, Positive Forms, Spectral Theory, Further Properties of Normal Operators.

UNIT-IV: Bilinear Forms, Definition and examples, symmetric and skew-symmetric bilinear forms, real quadratic forms, The matrix of a bilinear form, Orthogonality, Classification of bilinear forms.

** Any other advancement in this field may be incorporated.

References:

1. Hoffman and Kunze, LinearAlgebra.
2. A. R. Rao and P. Bhimashankaram, Linear Algebra. (Tata Mc-GrawHill)
3. Gilberd Strang, Linear Algebra and its Application, Academic Press.
4. S. Lang, Linear Algebra, Undergraduate Texts in Mathematics,Springer-Verlag.
5. P. Lax, Linear Algebra, John Wiley &Sons.
6. Ben Noble and James W. Daniel, Applied Linear Algebra (Prentice - Hall of India Private Ltd.)
7. Gareth Williams, Linear Algebra with applications, Narosa Publishing House.

Course Title: Continuum Mechanics
Course Code: MATH-203C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives*: Continuum mechanics is a branch of mechanics that deals with the mechanical behavior of materials modeled as a continuous mass rather than as discrete particles. The French mathematician Augustin-Louis Cauchy was the first to formulate such models in the 19th century. Continuum mechanics deals with physical properties of solids and fluids which are independent of any particular coordinate system in which they are observed. These physical properties are then represented by tensors, which are mathematical objects that have the required property of being independent of coordinate system. These tensors can be expressed in coordinate systems for computational convenience. Materials, such as solids, liquids and gases, are composed of molecules separated by space. On a microscopic scale, materials have cracks and discontinuities. However, certain physical phenomena can be modeled assuming the materials exist as a continuum, meaning the matter in the body is continuously distributed and fills the entire region of space it occupies. A continuum is a body that can be continually sub-divided into infinitesimal elements with properties being those of the bulk material.*

UNIT-I: Affine transformation, infinitesimal affine transformation. A geometrical interpretation of components of strain. Strain quadric of Cauchy. Transformation of strain component by changing the co-ordinate system. Principle strains, invariants, general infinitesimal deformation, compatibility equations, linear strain. Examples of strain. Finite deformation.

UNIT-II: Body and surface force, specification of stress at a point, equation of equilibrium, symmetry of stress tensor, boundary conditions, transformation of stress components from an co-ordinate to another and stress invariants. Stress quadric. Mohr's diagram, mean stress, stress ellipsoid. Octahedral, normal and shearing stresses. Purely normal stress. Examples of stress. Different formulae.

UNIT-III: Fluid motion by Euler and Lagrangian method, Equivalence of these two methods, different types of flows, stream lines and path lines, difference between them, velocity potential, rotational and irrotational motion, equation of continuity by Euler and Lagrange, particular case of equation of motion, condition for a surface to be a boundary surface.

UNIT-IV: Euler's dynamical equations, surface condition integration of the equation of motion, Bernoulli's theorem, equation of motion by flux method, Lagrange's hydrodynamical equation, Cauchy's integral, Performancy of irrotational motion, Helmotz's equation, Kelvin's circulation theorem.

UNIT-V: Motion in two dimensions, the current function, irrotational motion, source, sink and doublet, complex potential, image of a source w.r.t plane and a circle, image of a doublet w.r.t to a circle. Vorticity, properties of vortex filament, complex potential due to a rectilinear vortex, image of a vortex w.r.t a plane, circular cylinder, two infinite rows of vortices, Karman's vortex sheet.

** Any other advancement in this field may be incorporated.

References:

1. I. S. Sokolnikoff, Mathematical Theory of Elasticity , Tata Mc. Grawhill , 1997.
2. S.Valliappan, Continuum Mechanics , Oxford & IBH Publishing Co.1981.
3. P. D. S Verma, Theory of elasticity,Vikas Publishing House PVT LTD.
4. F. Charlton, Textbook of Fluid Dynamics, CBS Publishers, Delhi, 1985.
5. A. J. Choin and A. Morsden, A Mathematical Introduction to Fluid Dynamics, Springer Verlag, 1993.
6. L. D. Landau and E. M. Lipschitz, Fluid Mechanics, Pergamon Press, London, 1985.

Course Title: Functional Analysis
Course Code: MATH-204C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives:*Functional analysis is a branch of mathematical analysis which studies the transformations of functions and their algebraic and topological properties. Functional analysis has strong parallels with linear algebra, as both fields are based on vector spaces as the core algebraic structure. Functional analysis endows linear algebra with concepts from topology (e.g. inner product, norm, topological space) in defining the topological vector space.An important part of functional analysis is the extension of the theory of measure, integration, and probability to infinite dimensional spaces, also known as infinite dimensional analysis.*

UNIT-I: Normed linear spaces, Norms on $C[a,b]$, Banach spaces, the Banach spaces l^p $(1 \leq p < \infty$. the Function space $C(x)$, Basic results on L^p spaces, Equivalent norms, Finite dimentional normed linear spaces and their completeness, Convex sets in normed linear spaces and their properties, Quotient space of normed linear space and its completeness.

UNIT-II: Linear operators, Bounded linear operators, Normed linear spaces of bounded linear operators, Uniform boundedness theorem, Open mapping theorem, Closed graph theorem, Linear functionals, Hahn-Banach theorem, Dual space, Conjugate Spaces.

UNIT-III: Riesz Lemma, Fixed point theorem and its applications, Reflexivity of Banach spaces, Linear operators on normed spaces, finite dimensional normed spaces, direct sums and complementary subspaces, bounded linear operators, inverse operators, completion of normed spaces, Baire's Category Theorem, Spectral properties of Bounded Linear Operators.

UNIT-IV: Inner product spaces and their properties, Hilbert spaces, Orthonormal sets, Complete orthonormal sets, Bessel's inequality, Perseval's identity, Orthogonal complement and projection theorem, Completion of Inner Product Spaces, Projection on finite dimensional spaces, orthogonal projections on Hilbert spaces.

UNIT-V: Riesz representation theorem, Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert spaces, Self-adjoint operators, Continuous linear operators, Completely continuous operators, Positive operators, Projection operators, Normal operators, Unitary operators.

** Any other advancement in this field may be incorporated.

References:

1. Goffman C Pedrick, First Course in Functional Analysis, Prentic Hall of India, New Delhi.
2. Krishnan V K., Textbook of Functional Analysis: A Problem Oriented Approach, Prentice Hall of India.
3. B. V. Limaye, Functional Analysis, Wiley Eastern Ltd.
4. B. K. Lahiri, Functional Analysis, World Press Calcutta.
5. J. B. Conway, A Course in Functional Analysis, Springer Verlag, New York, 1990.
6. S. Ponnusamy, Foundations of Functional Analysis, Narosa.

Course Title: Mathematics for Social Sciences
Course Code: MATH-205OE
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: Mathematics is the most beautiful and most powerful creation of the human spirit. Nature used beautiful mathematics in creating the world. Mathematics is the art of giving the same name to different things. Everything around us is mathematics. Social Sciences are related to the study of social life, social change, and the social causes and consequences of human behaviour. Sociologists investigate the structure of groups, organizations, and societies, and how people interact within these contexts. The subject matter of social sciences is diverse ranging from crime to religion, the family to the state, the divisions of race and social class, and the shared beliefs of a common culture and social stability to radical change in whole societies. Mathematics for Social Sciences is an interdisciplinary field of research concerned both with the use of mathematics within sociological research as well as research into the relationships that exist between mathematical logic and social phenomena. It is in fact is combination of two seemingly completely different fields of academia and it provides the inherent mathematical understanding of various social issues and challenges.

Unit-I: Basic of calculus: Concept of derivative, partial derivative, integration, solution of simple differential equations.
Simple Ideas of Statistics and Probability Theory: Data manipulation, Measures of central tendency (Mean, Median, Mode), Variance, Standard deviation, Skewness and Kurtosis, Correlation and Regression, Basic Probability Theory, Construction process of Index numbers.

Unit-II: Use of Mathematics in Constructing Theoretical Models of Social Phenomena: Methodology of mathematical models, Construction and analysis of mathematical models on various social phenomena: Malthusian Growth model, Logistic Model, George Homan's The Human Group model, Rashevsky's social behaviour models, demand-supply models, Game theory models, Schelling model etc., interpretation of mathematical results from social point of view.

Unit-III: Models and Social Networks through Graphs: Definition and notations, Social Models using directed graphs, signed graphs, weighted graphs, un-oriented graphs, Small world problems using networks.

Unit-IV: Artificial Intelligence: Basic concepts and definitions. Use of artificial intelligence to interpret and analyze various social phenomena.

Unit-V: Stochastic differential equations: Definitions and Notation, Random Walk and Brownian Motion, White and Colour Noise, Diffusion Process, Kolmogorov Differential Equations, Wiener Process, Ito Stochastic Integral, Ito Stochastic Differential Equation, Application of Stochastic Differential Equations in socio mathematical models.

References:

1. Phillip Bonacich, Philip Lu: Introduction to Mathematical Sociology
2. Barbara Foley Meeker, Robert K. Leik: Mathematical Sociology
3. Charles A. Lave: An introduction to models in the social sciences
4. James Samuel Coleman: Introduction to mathematical Sociology
6. Peter Norvig, Stuart J. Russell: Artificial Intelligence: A Modern Approach
7. Philip C. Jackson: Introduction to Artificial Intelligence
8. S. K. Mapa: Real Analysis
9. Narsingh Deo: Graph Theory with application to Engineering and Computer Science
10. Linda J. S. Allen: An introduction to stochastic processes
11. B.R. Bhatt: Modern Probability Theory.

Course Title: Topology
Course Code: MATH-301C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives:*In mathematics, topology is concerned with the properties of a geometric object that are preserved under continuous deformations, such as stretching, twisting, crumpling and bending, but not tearing or gluing. The motivating insight behind topology is that some geometric problems depend not on the exact shape of the objects involved, but rather on the way they are put together. For example, the square and the circle have many properties in common: they are both one dimensional objects (from a topological point of view) and both separate the plane into two parts, the part inside and the part outside.*

UNIT-I: Topological spaces, Topological structures, Base and sub base for a topology, topologies generated by classes of sets, local bases, accumulation points, closed sets, closure of a set, derived sets, interior points, exterior points, boundary of a set, neighborhood & neighborhood system, Order topology, Product topology on X × Y, convergence and limit, coarser and finer topologies, subspaces, relative topologies, equivalent definition of topologies.

UNIT-II: Continuous function, continuity at a point, sequential continuity at a point, open and closed functions, homomorphic spaces, topological properties, topologies induced by functions, continuous functions, open maps, closed maps and homeomorphism,

UNIT-III: Separation axioms, separation by open sets, separation axioms and Ti spaces, subspaces, sum, product and quotient spaces, Urysohn's lemma and Metrization theorem, regular space, completely regular spaces, normal space, Tychonof space, completely normal, Housdroff space.

UNIT-IV: Countability, first countable spaces, second countable spaces, separation spaces and Lindeloff theorem, hereditaryproperties.Compact spaces, Covers, open covers, finite sub covers compact sets, reducible compact sets, sub set of a compact space, finite intersection property, compactness and Hausdorff spaces, sequentially compact sets, locally compactsets.

UNIT-V: Connectedness, separated sets, connected sets, connected spaces, connectedness on the real lines.Metrizable spaces**.** Definition and examples, properties, subspaces, product of metrizable spaces.

** Any other advancement in this field may be incorporated.

References:

1. J.R. Munkres, Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. J. Dugundji, Topology, Allyn and Bacon, 1966.
3. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.
4. J.L. Kelley, General Topology, Van Nostrand Reinhold Co., New York, 1995.
5. J. Hocking and G. Young, Topology, Addison-Wesley Reading, 1961.
6. L. Steen and J. Seebach, Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970.
7. B.C. Chatterjee, S. Ganguly and M.R.Adhikary, A Text Book of Topology, Asian Books Pvt. Ltd.

Course Title: Numerical Analysis with Computer Applications-I
Course Code: MATH-302C
Full Marks: 100 (End Term: 70 [Theory: 50, Practical: 20] + Internal: 30[Theory: 15, Practical: 15])
Credit: 4

Objectives:*Numerical analysis is the study of algorithms that use numerical approximation (as opposed to symbolic manipulations) for the problems of mathematical analysis (as distinguished from discrete mathematics). Numerical analysis naturally finds application in all fields of engineering and the physical sciences, life sciences, social sciences, medicine, business and even the arts have adopted elements of scientific computations, ordinary differential equations appear in celestial mechanics (predicting the motions of planets, stars and galaxies); numerical linear algebra is important for data analysis; stochastic differential equations and Markov chains are essential in simulating living cells for medicine and biology. Before the advent of modern computers, numerical methods often depended on hand interpolation formulas applied to data from large printed tables. Since the mid 20th century, computers calculate the required functions instead, but many of the same formulas nevertheless continue to be used as part of the software algorithms.*

Group-A: Theory

Unit-I:Gauss Elimination, Gauss-Jordan, LU Decomposition, Cholesky, LDV Decomposition, QR Decomposition, Uniqueness of decomposition methods, Operational counts for different methods, Gauss-Jacobi, Gauss-Seidel, S.O.R. and S.U.R. method (with rate of convergence), Partition Method, , Ill conditioned system and their solution methods, Error analysis.

Unit-II: Gerschgorin's circle theorem. Brauer's Theorem, Jacobi method, Given's method, House Holder's method, Rutishauser method, Power method, Inverse power method.

Unit-III: Ramanujan's method, Secant method, Muller's method, Chebyshev's method, Graeffe's Root Squaring Method, Birge Vieta method, Lin-Bairstow method, *Methods to solve a system of nonlinear equations:* General iterative method, Newton-Raphson method, Steepest descent method.

Unit-IV: Basic concepts, Forward, Backward, Central difference of different orders, Different types of boundary conditions, Implicit and explicit schemes, Different methods of Solution of elliptic (standard formula, 5-point diagonal method, method of residuals), parabolic (Schmidt, Crank-Nicolson, Richardson, Du Fort, Frankel method) and hyperbolic type of partial differential equations, Poisson's equation.

Group-B: Practical

1. Gauss-Jordon method. , 2. Inverse of a matrix , 3. S.O.R. / S.U.R. method , 4. Relaxation method, 5. Solution of one dimensional heat equation, 6. Solution of Laplace equation. , 7. Solution of Poisson equation.
8. Solution of one dimensional wave equation.

** Any other advancement in this field may be incorporated.

References:

1. Isacson and Keller*: Analysis of Numerical methods*
2. Ralston and Rabinowitz*: A first course in Numerical Analysis*
3. M.K.Jain: *Numerical solution of differential equations*
4. G.D.Smith *: Numerical solution of partial differential equations*.
5. O.C.Zienkiewics: *The finite element method in structural and continuum mechanics*
6. A.R.Mitchell: *The finite elements method in partial differential equations*

Course Title: Graph Theory
Course Code: MATH-303C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In mathematics, graph theory is the study of graphs, which are mathematical structures used to model pair wise relations between objects. A graph in this context is made up of vertices (also called nodes or points) which are connected by edges (also called links or lines). A distinction is made between undirected graphs, where edges link two vertices symmetrically, and directed graphs, where edges link two vertices asymmetrically; see Graph (discrete mathematics) for more detailed definitions and for other variations in the types of graph that are commonly considered. Graphs are one of the prime objects of study in discrete mathematics.*

Unit-I: Concept of a graph, definition and notations of a graph, vertices, different types of vertices and edges, loops, simple graphs, general graph, p seudo graph, multi graph, directed and undirected graph, representation of a graph, pendant vertex, degree and parity of a vertex, relation between the sum of the degree of vertices and the member of edges, an undirected graph has an even number of vertices of odd degree, walk, path, connectivity, connected graph, diameter of a connected graph, sub graph, simple problems.

Unit-II: Connected components, cut points, bridges, traversible multigraphs, Konigsberg problem and its solution, Eulerian graph, Eulerian graph, Eulerian trails, any finite connected graph G with two odd vertices is traversable. Hamiltonian graph, a Hamiltonian graph need not be Eulerian and vice-versa, G is not connected implies G^c is connected. Simple problems.

Unit-III: Definition of a cycle, Every (p, q) graph where $q \geq p$ contains a cycle, every (p,q) graph with $q \geq p - 1$ is either connected or contains a cycle, theorem regarding disconnectivity of a graph G existence of a path joining two vertices, maximum number of a degree in a simple graph with n vertices and K components.

Unit-IV: Matrices and graphs, incident and adjacent matrices, drawing of graph whose adjacent matrix is given, adjacent structure representation of a graph, labeled graph isomorphic and homomorphic graphs, their identifications. Simple problems.

Unit-V: Complete tripartite graph, trees, conditions for a graph to be a tree, a tree with n vertices has ($n – 1$) edges, minimally connected graph, a graph is a tree if it is minimally connected, theorem for connectivity of a graph, spanning tree, spanning trees in a weighted graph and minimal spanning tree, digraphs, Kirchoff theorem, tournaments, every tournament for Hamiltonian path, weighted graph, shortest path algorithm Drijkstra, Kruskal and Warshall algorithms.

** Any other advancement in this field may be incorporated.

References:

1. F. Harary, Graph Theory, Addision – Wesley Publishing Co., Reading, Mass(1969).
2. Deo Narsingh, Graph Theory with application to Engineering and Computer Science, Prentice Hall of India Pvt. Ltd., New Delhi 110001 (2006).
3. Edgar G Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, Prentice Hall of India Pvt. Ltd. New Delhi 110001 (2007)
4. T. Veerarajan, Discrete Mathematics w ith Graph Theory and Combinatories, McGraw Hill Education (India) Pvt. Ltd. New Delhi 110018 (2007)

Course Title: Integral Transforms and Integral Equations
Course Code: MATH-401C
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives:*In mathematics, integral equations are equations in which an unknown function appears under an integral sign. There is a close connection between differential and integral equations, and some problems may be formulated either way. See, for example, Green's function, Fredholm theory, and Maxwell's equations. In mathematics, an integral transform maps a function from its original function space into another function space via integration, where some of the properties of the original function might be more easily characterized and manipulated than in the original function space. The transformed function can generally be mapped back to the original function space using the inverse transform.*

Unit-I: Fourier transform: Existence, Uniqueness, Inversion, Applications to ODE &PDE, Fourier integral Theorem, Fourier transform of the derivative. Derivative of Fourier transform. Fourier transforms of some useful functions. Fourier cosine and sine transforms. Convolution. Properties of convolution function. Convolution theorem.

Unit-II: Mellin Transform and its inverse. Application to Boundary value problems. Hankel Transforms and its inverse. Application to Boundary value problems. Z-transform : Definition and properties. Z-transform of some standard functions. Inverse Z-transforms. Applications.

Unit-III: Introduction. Linear integral equations of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. 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.

Unit-IV: Solution by the method of successive approximations. Iterated kernels. Reciprocal kernels. Volterra's solution of Fredholm's integral equation. Fredholm theory for the solution of fredholm's integral equation. Fredholm's determinant $D(\lambda)$. Fredholm's first minor D(x,y,lamda) Fredholm's first and second fundamental relations. Fredholm's p-th minor. Fredholm's first, second and third fundamental theorems. Fredholm's alternatives.

Unit-V: Hilbert-Schmidt theory of symmetric kernels. Properties of symmetric kernels. Existance of characteristic constants. Complete set of characteristic constants and complete orthonoralmised system of fundamental functions. Expansion of iterated kernel in terms of fundamental functions. Schmidt's solution of Fredholm's integral equations.

** Any other advancement in this field may be incorporated.

References:

1. J. W. Brown and R. Churchill, Fourier Series and Boundary Value Problems, McGraw Hill, 1993.
2. G. F. Roach, Green's Functions,Cambridge University Press,1995.
3. S. G. Mikhlin, Integral Equations, The MacMillan Company, New york,1964.
4. Lokenath Debnath and Dambaru Bhatta, Integral Transforms and Their Applications (Chapman &Hall/CRC).
5. Lovitt : Linear Integral Equations.
6. Tricomi : Integral Equations.
7. M. D. Raisinghania, Integral Transforms, S. Chand.

Course Title: Numerical Analysis with Computer Applications-II
Course Code: MATH-402C
Full Marks: 100 (End Term: 70 [Theory: 40, Practical: 30] + Internal: 30[Theory: 15, Practical: 15])
Credit: 4

Objectives*:Numerical analysis is the study of algorithms that use numerical approximation (as opposed to symbolic manipulations) for the problems of mathematical analysis (as distinguished from discrete mathematics). Numerical analysis naturally finds application in all fields of engineering and the physical sciences, life sciences, social sciences, medicine, business and even the arts have adopted elements of scientific computations, ordinary differential equations appear in celestial mechanics (predicting the motions of planets, stars and galaxies); numerical linear algebra is important for data analysis; stochastic differential equations and Markov chains are essential in simulating living cells for medicine and biology. Before the advent of modern computers, numerical methods often depended on hand interpolation formulas applied to data from large printed tables. Since the mid 20th century, computers calculate the required functions instead, but many of the same formulas nevertheless continue to be used as part of the software algorithms*

Group-A: Theory

Unit-I: Approximate solution of Fredholm equation by finite sums and degenerate Kernels, Numerical solution of Volterra equations.

Unit-II: *Weighted residual and variational methods:* Collocation, Sub-domain, Least square, Galerkin, Petrov-Galerkin, Ritz method.
Finite element methods: Basic concepts and definitions of finite element, Linear and quadratic shape functions of line element, triangular element and quadrilateral element in natural coordinates, Solutions of differential equations using shape functions.

Unit-III: Gaussian Quadrature. Numerical integration over finite elements (line, triangular and quadrilateral).

Group-B: Practical

1. Solution of ordinary differential and partial differential equation by weighted Residual method:
    a. Least square method. b. Galerkin method.
2. Solution of simple boundary value problem by
    a. Finite element and b. Boundary element method.
3. Solution of system of Non-linear equations by Newton‟s method. 4. Method of steepest descent.

** Any other advancement in this field may be incorporated.

References:

1. Berzin and Zhidnov*: Computing methods*
2. Isacson and Keller*: Analysis of Numerical methods*
3. Ralston and Rabinowitz*: A first course in Numerical Analysis*
4. M.K.Jain: *Numerical solution of differential equations*
5. G.D.Smith *: Numerical solution of partial differential equations*.
6. O.C.Zienkiewics: *The finite element method in structural and continuum mechanics*
7. A.R.Mitchell: *The finite elements method in partial differential equations*
8. Prem K. Kytbe*: An introduction to boundary element method.*
9. B.P.Demidovich and J.A.Maron*: Computational Mathematics*
10. A. Gourdin& M. Boumahrat: *Applied Numerical Methods*

Course Title: Probability and Statistics
Course Code: MATH-301E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *Probability is the branch of mathematics concerning numerical descriptions of how likely an event is to occur, or how likely it is that a proposition is true. The probability of an event is a number between 0 and 1, where, roughly speaking, 0 indicates impossibility of the event and 1 indicates certainty. These concepts have been given an axiomatic mathematical formalization in probability theory, which is used widely in areas of study such as mathematics, statistics, finance, gambling, science (in particular physics), artificial intelligence, machine learning, computer science, game theory, and philosophy to, for example, draw inferences about the expected frequency of events. Probability theory is also used to describe the underlying mechanics and regularities of complex systems. Statistics is the discipline that concerns the collection, organization, analysis, interpretation and presentation of data. In applying statistics to a scientific, industrial, or social problem, it is conventional to begin with a statistical population or a statistical model to be studied. Statistics deals with every aspect of data, including the planning of data collection in terms of the design of surveys and experiments.*

Unit-I: Algebra of sets, fields and σ - fields, minimal fields, closure property of a field under finite unions and intersections of arbitrary number of fields, Borel field, point function and set function, inverse function, measurable function, Borel function, induced σ - field, random variable, condition for a variable to be random, σ - field induced by a random variable, limits of random variables.

Unit-II: Moment generating function and characteristics function their properties, uniqueness of these functions, conditions for a function to be characteristic function, inversion theorem of levy, distribution function in bivariate case, bivariate normal distribution. Chebychev's inequality and its generalized form, Markov and Jensen inequations, Convergence in probability, Weak law of Large numbers (WLLN), condition for WLLN to hold, Bernoulli's law for large numbers, Markov and Khinchin's theorem.

Unit-III: Probability generating function (pgf), pgf for the sum of independent variables, Demoivre-Laplace theorem, Some particular distributions on the real lines namely namely uniform distribution,exponential lack of memory property, exponential distribution possesses lack of memory, connection between Poisson's and exponential distribution, x^2 distribution, *t* distribution, Central limit theorem (CLT), CLT for *iid* cases, Lindeberg-Levy theorem,Simple problems.

Unit-IV: Universe and sample different types of sampling, sampling distributions, standard error, asymptomatic distributions, stationary distribution, methods of estimation, properties of estimators, confidence intervals, test of hypothesis, likelihood ratio-test, analysis of discrete data, chisquare, test of goodness of fit, simple problems.

Unit-V: Statistical hypothesis, minimizing two types of errors, level of significance, Neyman-Pearson lemmas test of significance based on *t*, x^2 distribution, partial and multiple correlation. Simple problems.

** Any other advancement in this field may be incorporated.

References:

1. B.R. Bhatt, Modern Probability Theory, New Age International Publishers, New Delhi (2015).
2. B.V. Gnedenko, Theory of Probability, Mir Publication, Moscow (1976).
3. A. Gupta, Ground work of Mathematical Probability and Statistics, Academic Press, Kolkata (2018).
4. Vladimir Rotor, Probability Theory, Allied Publishers, Kolkata (2003).
5. W. Feller, Introduction to Probability theory and its application,Vol.-I, Wiley Eastern, New York, (1968).
6. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, S. Chand, New Delhi.
7. J. N. Kapoor and H. C. Saxena, Mathematical Statistics, S. Chand, New Delhi (2009).
8. P. Mukhopadhyaya, Mathematical Statistics, New Central Book Agency, Kolkata (1996).

Course Title: Operations Research
Course Code: MATH-302E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives*:Operations research (OR) is a discipline that deals with the application of advanced analytical methods to help make better decisions, capability development, management and assurance. The terms management science and decision science are sometimes used as synonyms. Employing techniques from other mathematical sciences, such as mathematical modeling, statistical analysis, and mathematical optimization, operations research arrives at optimal or near-optimal solutions to complex decision-making problems. Because of its emphasis on human-technology interaction and because of its focus on practical applications, operations research has overlap with other disciplines, notably industrial engineering and operations management, and draws on psychology and organization science. Operations research is often concerned with determining the extreme values of some real-world objective: the maximum (of profit, performance, or yield) or minimum (of loss, risk, or cost).*

UNIT-I: Introduction of Goal Programming (GP). Concept of GP, Difference between LP & GP approach, GP as an extension of LP. Single goal models, multiple goals models, multiple goals with priorities, multiple goals with priorities and weights. Formulation of GP models. Graphical solution-method of GP, Modified simplex method of GP. The GP algorithm : Extended simplex algorithm.

UNIT-II: Introduction of dynamic programming, characteristic of dynamic programming, deterministic and probabilistic dynamic programming, Bellman's principle of optimality, minimum path problem, single additive constraint, multiplicatively separable return, additively separable return, single multiplicative constraint, system involving more than one constraint, formulation of multistage model, forward and backward recursive approach, solving linear and non-linear programming problems.

UNIT-III. Origin of travelling salesman problem, Symmetrical and asymmetrical problems, Mathematical representation of problems, Solution techniques for such problems using zero assignment/unit assignment etc. Introduction of geometric programming. Formulation of geometric programming problem (unconstrained type), geometric arithmetic mean inequality, general formulation of geometric programming problem (unconstrained type), derivation of necessary conditions for optimality, constrained geometric programming, complementary geometric programming, geometric programming problem with equality constraints, conditions for normality and orthogonality.

UNI-IV: Introduction of theory of games. Basic idea of theory of games. Payoff matrix. Rectangular games, Strategies, Pure and Mixed strategy problems, Minimax/Maximin criterion, Saddle point, Graphical method of solving $2 \times n$ and $m \times 2$ games, Dominance principle, Equivalence of rectangular games and solving games by linear programming and matrix method. Algebraic method for the solution of general game. Fuzzy game problem.

UNIT-V: Queueing Theory. Introduction, Queueing system, Queue disciplines FIFO, LIFO, SIRO, FILO etc. 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 s (distribution of departures), Derivation of service time distribution, Kendals notations, Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space.

** Any other advancement in this field may be incorporated.

References*:*

1. F. S. Hiller and G.C. Leiberman, Introduction to Operations Research, McGraw-Hill, 1995.
2. B. S. Goel and S. K. Mittal, Operations Research, Pragmatic Prakashan.
3. Kasana and Kumar, Introductory Operations Research, Springer.
4. Kanti Swarup, P.K. Gupta and Man Mohan, Operations Research, Macmillan.
5. J. K. Sharma, Operations Research: Theory and Applications, McMillan, 2013.
6. P. K. Gupta and D.S. Hira, Operations Research, S. Chand.
7. S. D. Sharma, Operations Research, Theory, methods & applications, Kedar Nath Ram Nath.

Course Title: Fuzzy Set Theory and Applications
Course Code: MATH-303E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In mathematics, fuzzy sets (a.k.a. uncertain sets) are somewhat like sets whose elements have degrees of membership. n classical set theory, the membership of elements in a set is assessed in binary terms according to a bivalent condition — an element either belongs or does not belong to the set. By contrast, fuzzy set theory permits the gradual assessment of the membership of elements in a set; this is described with the aid of a membership function valued in the real unit interval [0, 1]. Fuzzy sets generalize classical sets, since the indicator functions (aka characteristic functions) of classical sets are special cases of the membership functions of fuzzy sets, if the latter only take values 0 or 1.In fuzzy set theory, classical bivalent sets are usually called crisp sets. The fuzzy set theory can be used in a wide range of domains in which information is incomplete or imprecise, such as bioinformatics.*

Unit-I: Fuzzy sets, Definition of fuzzy sets, fuzzy point, α-level sets, convex fuzzy sets, basic operations on fuzzy sets, cardinality of fuzzy sets and relative cardinality of fuzzy sets. Cartesian products, algebraic products, bounded sum and difference, t-norms and t-conorms, quasi-coincidence of two fuzzy sub sets, rough sets (definition and example), idea of soft sets.

Unit-II: L- fuzzy sets, interval- valued fuzzy sets, type -2 fuzzy sets, intuitionistic fuzzy sets and set operations of intuitionistic fuzzy sets, Zadeh's extension principle. Fuzzy numbers, triangular fuzzy numbers, fuzzy numbers describing 'Large' , Fuzzy numbers in the set of integers , arithmetic operations on intervals and fuzzy numbers.

Unit-III: Fuzzy relations on fuzzy sets, composition of fuzzy relations, max-min and min-max compositions, basic properties of fuzzy relations, relation between max-min and min-max compositions, fuzzy pre order relations, fuzzy semi pre order relations and fuzzy order relations fuzzy equivalence relations, fuzzy compatibility relations, fuzzy graphs, fuzzy similarity relations, examples of different fuzzy relations.

Unit-IV: Fuzzy functions on fuzzy sets, image and inverse image of fuzzy sets and some basic theorems on fuzzy functions.

Unit-V: Sum, multiplication of two fuzzy matrices, idempotent fuzzy matrix and their properties. Different methods of defuzzification, decision making in fuzzy environment and some mathematical models in fuzzy environment.

** Any other advancement in this field may be incorporated.

References :

1. H. J. Zimmermann, Fuzzy Set Theory and its applications, Allied publications Ltd. 1991.
2. G. J. Klir and B. Yuan, Fuzzy sets and Fuzzy Logic, Prentice Hall of India, 1995.
3. G. Bojadziev and M. Bojadziev , Fuzzy Sets, Fuzzy Logic, Applications, World Sci., 1995.

Course Title: Nonlinear Dynamics
Course Code: MATH-304E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In mathematics and science, a nonlinear system is a system in which the change of the output is not proportional to the change of the input. Nonlinear problems are of interest to engineers, biologists, physicists, mathematicians, and many other scientists because most systems are inherently nonlinear in nature. Nonlinear dynamical systems, describing changes in variables over time, may appear chaotic, unpredictable, or counterintuitive, contrasting with much simpler linear systems. Typically, the behavior of a nonlinear system is described in mathematics by a nonlinear system of equations, which is a set of simultaneous equations in which the unknowns (or the unknown functions in the case of differential equations) appear as variables of a polynomial of degree higher than one or in the argument of a function which is not a polynomial of degree one.*

Unit-I: Linear autonomous systems, existence, uniqueness and continuity of solutions, diagonalization of linear systems, fundamental theorem of linear systems, the phase paths of linear autonomous plane systems, complex eigen values, multiple eigen values, stability theorem, reduction of higher order ODE systems to first order ODE systems, linear systems with periodic coefficients. The flow defined by a differential equation, linearization of dynamical systems (two, three and higher dimension), Stability: (i) asymptotic stability (Hartman's theorem), (ii) global stability (Liapunov's second method).

Unit-II: Translation property, limit set, attractors, periodic orbits, limit cycles and separatrix, Bendixon criterion, Dulac criterion, Poincare-Bendixon Theorem, index of a point, index at infinity. Stability and bifurcation, saddle-node, transcritical and pitchfork bifurcations, hopf- bifurcation, center manifold (linear approximation).

Unit-III: Difference equations, existence and uniqueness of solutions, linear difference equations with constant coefficients, systems of linear difference equations, qualitative behavior of solutions to linear difference equations.Steady states and their stability, the logistic difference equation, systems of nonlinear difference equations, stability criteria for second order equations, stability criteria for higher order system.

Unit-IV: Delay differential equations:Definitions and Notations, Applications, solution, stability analysis. Stochastic differential equations:Definitions and Notation, Random Walk and Brownian Motion, White and Colour Noise, Diffusion Process, Kolmogorov Differential Equations, Wiener Process, Ito Stochastic Integral, Ito Stochastic Differential Equation.

Unit-V: Chaos,Feigenbaum's number, Lyapunov exponents, Butterfly effect, Examples of Chaos in various dynamical systems like Lorenz system, Rosselor system, One-dimensional logistic map etc. Numerical simulations using MATLAB.

** Any other advancement in this field may be incorporated.

References:

1. D. W. Jordan and P. Smith (1998):Nonlinear Ordinary Equations- An Introduction to Dynamical Systems (Third Edition), *Oxford Univ.Press.*
2. *L. Perko (1991):* Differential Equations and Dynamical Systems, *Springer Verlag.*
3. *F. Verhulust (1996):* Nonlinear Differential Equations and Dynamical Systems, *Springer Verlag.*
4. *Alligood, Sauer, Yorke (1997):* Chaos- An Introduction to Dynamical Systems, *Springer Verlag.*
5. *W. G. Kelley and A. C. Peterson (1991):* Difference Equations- An Introduction with Applications, *Academic Press.*
6. *Rudra Pratap (1996): Getting started with MATLAB, Oxford.*

Course Title: Mathematical Elasticity
Course Code: MATH-305E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to plasticity, in which the object fails to do so and instead remain in its deformed state. The physical reasons for elastic behavior can be quite different for different materials. In metals, the atomic lattice changes size and shape when forces are applied (energy is added to the system). When forces are removed, the lattice goes back to the original lower energy state. For rubbers and other polymers, elasticity is caused by the stretching of polymer chains when forces are applied.*

Unit-I: Equations of equilibrium motion in terms of displacements, Hooke's law. Generalized Hooke's law. Various cases of Elastic symmetry of a body. The strain energy function and its connection with Hooke's law. Betti's identity. Clapeyrons formula and Clapeyrons theorem. Fundamental boundary value problems. Uniqueness and existence of solutions. Saint Venant's principle.

Unit-II: Extension, Bending, Torsion and Flexure of beams : Solution of torsion problem as Dirichlet or Neumann boundary value problem. Prandtl's Analogy.

Unit-III: Conformal mapping and the general problem of Flexure. Transverse bending. Problem of Torsion and Flexure for circular and elliptic bar. Torsion of circular shafts of variable diameter.

Unit-IV: Plane strain and plane stress. Generalized plane stress. Airy's stress function. Solution of plane problems by means of polynormials. General Equations of the plane problems in polar co ordinates.

Unit-V: Stress-strain relations, Differential equations of heat conduction, Basic equation in dynamical thermo elasticity, Thermo elastic vibrations and waves.

** Any other advancement in this field may be incorporated.

References:

1. A. E. Love, A Treatise on The Mathematical Theory of Elasticity.
2. I. S. Sokolnikoff , Mathematical Theory of Elasticity.
3. S. Timoshenko and J. N.Goodier, Theory of Elasticity.
4. A. S. Saada, Elasticity.Theory and Applications.
5. Y. C. Fung, Foundations of Solid Mechanics.
6. Y. A. Amenzade, Theory of Elasticity.
7. ZhilunXu, Applied Elasticity.
8. J. D.Achenbach, Wave Propagations in Elastic Solids.
9. A. C.Eringen, Elasto Dynamics.
10. K. F. Graff , Wave Motion in Elastic Solids.
11. Chi-TheWang, Applied Elasticity.

Course Title: Fluid Dynamics
Course Code: MATH-306E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In physics and engineering, fluid dynamics is a subdiscipline of fluid mechanics that describes the flow of fluids—liquids and gases. It has several subdisciplines, including aerodynamics (the study of air and other gases in motion) and hydrodynamics (the study of liquids in motion). Fluid dynamics has a wide range of applications, including calculating forces and moments on aircraft, determining the mass flow rate of petroleum through pipelines, predicting weather patterns, understanding nebulae in interstellar space and modelling fission weapon detonation. Fluid dynamics offers a systematic structure—which underlies these practical disciplines—that embraces empirical and semi-empirical laws derived from flow measurement and used to solve practical problems. The solution to a fluid dynamics problem typically involves the calculation of various properties of the fluid, such as flow velocity, pressure, density, and temperature, as functions of space and time.*

Unit-I: Bernoulli's equation. Impulsive action equations of motion and equation of continuity in orthogonal curvilinear co- ordinate. Euler's momentum theorem and D'Alemberts paradox.

Unit-II: 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.
Dimensional irrotational motion.

Unit-III: 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. Schwartz-Chirstoffel theorem.

Unit-IV: Motion of a sphere. Stoke's stream function. Source, sinks, doublets and their images with regards to a plane and sphere. Vortex motion. Vortex line and filament equation of surface formed by stream lines and vortex lines in case of steady motion. Strength of a filament.

Unit-V: Velocity field and kinetic energy of a vortex system. Uniqueness theorem rectilinear vortices. Vortex pair. Vortex doublet. Images of a vortex with regards to plane and a circular cylinder. Angle infinite row of vortices. Karman's vortex sheet Waves: Surface waves. Paths of particles. Energy of waves. Group velocity. Energy of a long wave.

** Any other advancement in this field may be incorporated.

References:

1. A. S. Ramsay (Bell), Hydrodynamics.
2. H. Lamb (Cambridge), Hydrodynamics.
3. L. D. Landou and E. M. Lifchiz (Pergamon), Fluid Mechanics,1959.
4. L. M. Thomson, Theoritical Hydrodynamics.
5. I. M. Milne-Thomson, Theoritical Aerodynamics, Macmillan, 1958.
6. Shih-I.Pai, Van Nostrand, Introduction to the theory of compressible flow, 1959.
7. P. Niyogi, Inviscid Gas Dynamics, Mcmillan,1975.
8. K. Oswatitsch, Gas Dynamics, Academic Press,1956.

Course Title: Vedic Mathematics
Course Code: MATH-307E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: Vedic Mathematics is a super-fast way of calculation whereby you can do supposedly complex calculations like 996 x 998 in less than five seconds flat. It is highly beneficial for school and college students and students who are appearing for their entrance examinations. Vedic Mathematics is far more systematic, simplified and unified than the conventional system. It is a mental tool for calculation that encourages the development and use of intuition and innovation, while giving the student a lot of flexibility, fun and satisfaction. It means giving them a competitive edge, a way to optimize their performance and gives them an edge in mathematics and logic that will help them to shine in the classroom and beyond. Therefore, it's direct and easy to implement in schools – a reason behind its enormous popularity among academicians and students. It complements the mathematics curriculum conventionally taught in schools by acting as a powerful checking tool and goes to save precious time in examinations. The methods & techniques are based on the pioneering work of late *Swami Shri. Bharati Krishna Tirthaji, Shankracharya of Puri*, who established the system from the study of ancient Vedic texts coupled with a profound insight into the natural process of mathematical reasoning. There are just 16 Sutras or Word Formulae which solve all known mathematical problems in the branches of Arithmetic, Algebra, Geometry and Calculus. They are easy to understand, easy to apply and easy to remember. Moreover, Vedic Mathematics is an integral part of Indian Knowledge System.

Unit – I: Addition, Subtraction and Multiplication with recognizable patterns: Multiplication of any number by 9, 99, 999, 9999,99999, Introduction to Sutras, High Speed Addition, Fast Subtraction using complement, Multiplication by 11, 111, 1111, Multiplication by 12,13,...19, Multiplication by 112, 1112, History of Vedic mathematics.

Unit – II: Base multiplication: Multiplication by numbers below the base, Multiplication by numbers above the base, Multiplication of 3 numbers near a certain base, Multiplication of numbers with different working base, Working base multiplication, Decimal Multiplication.

Unit – III: Generic and Algebraic multiplication: Multiplication by two-digit numbers, Multiplication by three and four-digit numbers, Multiplication of algebraic equations having two terms, Multiplication of algebraic equations with large power of variables, Special cases, Digital roots.

Unit – IV: Division: Divisibility, Division by numbers less than the base, Division by numbers more than the base, Long Division in one-line, Fractional division, Divisibility by prime numbers, Factorizing quadratic expressions, Algebraic division, Factorization of cubic.

Unit – V: Squaring and Cubing: Square of numbers in patterns, Square of number above the base, Square of number below the base, Square of any number using duplex, Cubes of numbers, Cube of number above the base, Cube of number below the base, Cube of any number. Square roots and Cube roots: square roots of exact squares, Square Roots of imperfect squares, Easy Square Roots of Exact squares, Square Roots of decimal numbers, Cube roots of exact cubes, Quick Cube Roots of Exact cubes.

** Any other advancement in this field may be incorporated.

References:
1. Vedic Mathematics for All Ages, Author:Vandana Singhal, *Motilal Banarsidass Publishers*.
2. Vedic Mathematics by Bharati Krishna Tirthaji Maharaja, Author: V. S. Agarwala, Motilal Banarsidass Publishers.
3. How to Become A Human Calculator, Author: Aditi Singhal, S Chand Publishing House.

Course Title: Discrete Mathematics
Course Code: MATH-401E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *Discrete mathematics is the study of mathematical structures that are fundamentally discrete rather than continuous. In contrast to real numbers that have the property of varying "smoothly", the objects studied in discrete mathematics – such as integers, graphs, and statements in logic. Concepts and notations from discrete mathematics are useful in studying and describing objects and problems in branches of computer science, such as computer algorithms, programming languages, cryptography, automated theorem proving, and software development. Conversely, computer implementations are significant in applying ideas from discrete mathematics to real-world problems, such as in operations research*.

Unit-I: Mathematical Logic:Propositions, truth tables, logical equivalence, algebra of propositions, conditional propositions, converse, contrapositive, inverse statements, biconditional statements, tautology and contradiction, normal forms, methods of proofs, rules of inference, predicate calculus, inference theory of predicate calculus. Simple problems.

Unit-II: Boolean algebra, unique features, basic operations, Boolean function, DeMorgan theorem, Logic gate, sum of product and product of sum form, normal form, expression of a Boolean function as a canonical form, simplification of Boolean expressions, Boolean expression from logic and switching network, implementation of logic expressions with logic gates and switching circuits. Simple problems.

Unit-III: Combinatorics: Pascal's identity, Vandermonde's identity, principle of inclusion and exclusion, the pigeonhole principle and its generalization, recurrence relation, particular solution, solution of recurrence relation by using generating function, derangement, principle of mathematical induction, well ordering principle. Simple problems.

Unit-IV: Divisibility theory, factorization in prime numbers, perfect numbers, Mersene numbers, Fermat numbers. Fermat's theorem. Gauss function, Mobius function, congruences and its elementary properties. Complete and reduced residue system, Euler's phi function, indeterminate equations, sum of two squares.

Unit-V: Quadratic residues and congruences of second degree in one unknown. Legendre symbols, quadratic reciprocity, nonlinear Diophantine equation, Ferma's last theorem, Pell's equation, Catalan relation, Beal's equation, sum of two squares. Simple problems.

** Any other advancement in this field may be incorporated.

References:

1. T. Veer Ranjan, Discrete Mathematics with Graph Theory and Combinatories, Megrawhill Education (India) Pvt. Ltd, New Delhi (2007).
2. Thomas Koshy, Elementary Number Theory with Applications, Academic Press, USA (2005).
3. S. K. Sarkar, A Text Book of Discrete Mathematics, S. Chand, New Delhi (2012).
4. D. S. Chandra Sekharaiah, Discrete Mathematical structures, Prism Books Pvt. Ltd., Bangalore (2001).
5. C. Y. Hsing, Elementary Theory of numbers, Allied Publishers, Kolkata (1995).

Course Title: Advanced Operations Research
Course Code: MATH-402E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives:*Operations research (OR) is a discipline that deals with the application of advanced analytical methods to help make better decisions, capability development, management and assurance. The terms management science and decision science are sometimes used as synonyms. Employing techniques from other mathematical sciences, such as mathematical modeling, statistical analysis, and mathematical optimization, operations research arrives at optimal or near-optimal solutions to complex decision-making problems. Because of its emphasis on human-technology interaction and because of its focus on practical applications, operations research has overlap with other disciplines, notably industrial engineering and operations management, and draws on psychology and organization science. Operations research is often concerned with determining the extreme values of some real-world objective: the maximum (of profit, performance, or yield) or minimum (of loss, risk, or cost).*

Unit-I: Introduction of sequencing problems, solution of sequencing problems, processing njobs through 2 machines, Johnson's algorithm for n jobs through 2 machines, processing njobs through 3 machines, processing of 2 jobs through m machines, graphical method, processing njobs through *m* machines.

Unit-II: Introduction of project management by PERT-CPM, historical development of PERT/CPM techniques, difference between applications of PERT and CPM techniques, basic steps in PERT and CPM techniques, network diagram representation, PERT and CPM Network components and precedence relationship, rules for drawing network diagram. Project scheduling by PERT and CPM, construction of a network, Fulkerson's i - j rule, errors and dummies in network. Critical path analysis, shortest route model, forward and backward pass methods, floats of an activity, project costs by CPM, crashing of an activity, crash-cost slope, project time-cost, trade off. solution of network problems using simplex technique, probability of completion of a project within a scheduled time.

Unit-III: Introduction of replacement problem, types of replacement problems, replacement of capital equipment that varies with time, replacement policy for items where maintenance cost increases with time and money value is not considered, replacement policy for item whose maintenance cost increases with time and money value changes at a constant rate, group replacement policy, individual replacement policy, mortality theorem, recruitment and promotion problems.

Unit-IV: Introduction of inventory system, direct inventories, indirect inventories, types of inventory models, inventory decisions, costs involved in inventory problems, variables in inventory problem, deterministic inventory models, concept of average inventory, concept of Economic Ordering Quantity (EOQ), EOQ model without shortage : economic lot size system with uniform demand, economic lot size with different rate of demand in different cycles, economic lot size with fine rate of replacement (EOQ production model). EOQ model when shortages are allowed : EOQ with constant rate of demand scheduling time constant, EOQ with constant rate of demand scheduling time variable, production size model with shortages.

UNIT-V: Multi-item deterministic models (the EOQ with constraints) : multi-item with one constant, limitation on investment, limitation on inventories, limitation on floor space (storage space). Fixed order quantity system with variable lead time. Deterministic models with price break. Probabilistic inventory models : inventory problems with uncertain demand, determination of safety stock under normal distribution of demand (lead time is fixed), Stochastic inventory models : Instantaneous demand, no set-up cost model, Uniform demand, no set-up cost model.

** Any other advancement in this field may be incorporated.

References :

1. F.S. Hiller and G.C. Leiberman, Introduction to Operations Research, McGraw-Hill, 1995.
2. Kanti Swarup, P.K. Gupta and Man Mohan, Operations Research, Macmillan.
3. J.K. Sharma, Operations Research: Theory and Applications, McMillan, 2013.
4. G. Hadly, Nonlinear and Dynamic Programming, Addison Wesley.
5. P.K. Gupta and D.S. Hira, Operations Research, S. Chand.
6. S.D. Sharma, Operations Research, Theory, methods & applications, Kedar Nath Ram Nath.

Course Title: Fuzzy Topology
Course Code: MATH-403E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives*: Fuzzy topology is the generalization of general topology. Fuzzy topology has applications like refomrulation, of and generalization of, algebraic geometry and catalyzed modern theory of dynamical systems. Very recently fuzzy topology techniques are being applied to the N-body orbital simulations in vector fields, in order to visualize a new theory of gravity.*

Unit-I: Fuzzy topology: Chang's definition and Lowen's definition, basic concepts, fuzzy open sets, fuzzy closed sets, fuzzy interior & fuzzy closure , fuzzy continuous function, lower (upper) semi continuous functions, their basic properties, subspaces, product spaces, quotient spaces, intuitionistic fuzzy topological spaces.

Unit-II: Concept of induced fuzzy topology, weakly induced fuzzy topology–their basic properties, Relation between induced fuzzy topological space and its corresponding topological space, initial topological spaces.

Unit-III: Fuzzy T_0 space, fuzzy T_1 space, fuzzy Hausdorff space, fuzzy regular space, fuzzy normal space, properties and examples of these spaces.

Unit-IV: Properties of fuzzy filter and fuzzy net, fuzzy filter base and their properties, fuzzy cluster point. Convergence of fuzzy net. Fuzzy open cover, α-shading (α*-shading), fuzzy compactness in the sense of Chang, fuzzy compactness in the sense of Lowen, Comparison between different compactness, N – compactness and its properties.

Unit-V: Fuzzy countable axioms, q-separated sets, definition of fuzzy connectedness, examples and its properties, good extension of connectedness. Mixed Fuzzy Topology: Definition and different types of mixed fuzzy topology and their properties.

** Any other advancement in this field may be incorporated.

References:

1. N. Palaniappan, Fuzzy Topology, Norosa 2006.
2. H. J. Zimmermann, Fuzzy Set Theory and its applications, Allied Publications Ltd. 1991.

Course Title: Mathematical Biology
Course Code: MATH-404E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives*: Mathematical and theoretical biology is a branch of biology which employs theoretical analysis, mathematical models and abstractions of the living organisms to investigate the principles that govern the structure, development and behavior of the systems, as opposed to experimental biology which deals with the conduction of experiments to prove and validate the scientific theories. The field is sometimes called mathematical biology or biomathematics to stress the mathematical side, or theoretical biology to stress the biological side. Theoretical biology focuses more on the development of theoretical principles for biology while mathematical biology focuses on the use of mathematical tools to study biological systems, even though the two terms are sometimes interchanged. Mathematical biology aims at the mathematical representation and modeling of biological processes, using techniques and tools of applied mathematics and it can be useful in both theoretical and practical research. Describing systems in a quantitative manner means their behavior can be better simulated, and hence properties can be predicted that might not be evident to the experimenter. This requires precise mathematical models.Because of the complexity of the living systems, theoretical biology employs several fields of mathematics,and has contributed to the development of new techniques.*

Unit-I: Insect out break model- Spruce-Budworm model; Fishery models (constant harvesting, ratio dependent harvesting, harvesting effort); Compensation model, Depensation model, Critical depensation model, Allee effect (weak, strong, weak-strong), Delay models. Lotka-Volterra system of predator-prey interaction, Gauss's Model, Kolmogorov Model, Leslie Gower Model, Beddington-DeAngelis model, Competition models, Mutualism models, Holling's functional response of Type-I, II, III, IV. Delay models.

Unit-II: Three species simple and general food chain models, Models on one prey two competing predators. Delay models. Deterministic model of simple epidemic, Infection through vertical and horizontal transmission, General epidemic- Karmac-Mackendric Threshold Theorem, modeling of Venereal diseases, SIS, SIRS, SEIS type models. Delay models.

Unit-III: Basic enzyme reactions and rate equations, Michaelis-Menten rate equations, Lineweaver-Burk plot, Cooperative phenomena, Hill Function. Gene, Phenotype, Genotype, Allele, Gene pool, Homozygous, Heterozygous, Mendel's experiment, Dominant, Recessive, Hybrid, Fundamental genetic matrices, Hardy Weinberg Law, Correlation between Genetics Compositions, Application of Baye's theorem, Multiple alleles and application to blood groups, Models for genetic improvement.

Unit-IV: General balance law, Fick's law, Diffusivity of motile bacteria, Chemical basis for pattern formation, Conditions for diffusive instability in higher dimension, Gierer and Meinhardt Model, Lotka-Volterra diffusion system.

Unit-V: Models using Directed graphs, signed graphs, weighted graphs, unoriented graphs, Genetic graphs. MATLAB: Numerical simulations using MATLAB.

** Any other advancement in this field may be incorporated.

References:

1. H. I. Freedman - *Deterministic Mathematical Models in Population Ecology*
2. Mark Kot (2001): *Elements of Mathematical Ecology, Cambridge Univ. Press*.
3. D. Alstod (2001): *Basic Population Models of Ecology, Prentice Hall, Inc., NJ*.
4. N.T.J.Bailey (1975): *The Mathematical Theory of Infectious Diseases and its Application, 2nd edn. London, Griffin* .
5. J. D. Murray (1990*): Mathematical Biology, Springer and Verlag.*

Course Title: Advanced Mathematical Elasticity
Course Code: MATH-405E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In physics and materials science, elasticity is the ability of a body to resist a distorting influence and to return to its original size and shape when that influence or force is removed. Solid objects will deform when adequate loads are applied to them; if the material is elastic, the object will return to its initial shape and size after removal. This is in contrast to plasticity, in which the object fails to do so and instead remain in its deformed state. The physical reasons for elastic behavior can be quite different for different materials. In metals, the atomic lattice changes size and shape when forces are applied (energy is added to the system). When forces are removed, the lattice goes back to the original lower energy state. For rubbers and other polymers, elasticity is caused by the stretching of polymer chains when forces are applied.*

Unit-I: 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 a circular hole. An infinite Plate under the Action of Concentrated Forces and Moments.

Unit-II: 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-infiniteBody.

Unit-III: Theory of thin plates :Basic equations for bending of plates. Boundary conditions. Navier's and Levy solutions for rectangular plates. Circular Plate. Cylindrical Bending of Uniformly Loaded Plates.

Unit-IV: 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.

Unit-V: Solution of simple crack problem using integral equations and integral transform methods- line and penny shaped crack, determination of SIF, crack propogation, Branching and arrest phenomena.

** Any other advancement in this field may be incorporated.

Reference:

1. A Treatise on The Mathematical Theory of Elasticity – A. E.Love
2. Mathematical Theory of Elasticity - I.S.Sokolnikoff
3. Theory of Elasticity – S. Timoshenko and J. N.Goodier
4. Elasticity Theory and Applications – A. S.Saada
5. Foundations of Solid Mechanics – Y. C.Fung
6. Theory of Elasticity – Y. A.Amenzade
7. Wave Propagations in Elastic Solids – J. D.Achenbach
8. Elasto-dynamics – A. C.Eringen
9. Wave Motion in Elastic Solids – K. F.Graff
10. Applied Elastity – Chi-TheWang.

Course Title: Advanced Fluid Dynamics
Course Code: MATH-406E
Full Marks: 100 (End Term: 70 + Internal: 30)
Credit: 4

Objectives: *In physics and engineering, fluid dynamics is a sub-discipline of fluid mechanics that describes the flow of fluids—liquids and gases. It has several sub-disciplines, including aerodynamics (the study of air and other gases in motion) and hydrodynamics (the study of liquids in motion). Fluid dynamics has a wide range of applications, including calculating forces and moments on aircraft, determining the mass flow rate of petroleum through pipelines, predicting weather patterns, understanding nebulae in interstellar space and modelling fission weapon detonation. Fluid dynamics offers a systematic structure—which underlies these practical disciplines—that embraces empirical and semi-empirical laws derived from flow measurement and used to solve practical problems. The solution to a fluid dynamics problem typically involves the calculation of various properties of the fluid, such as flow velocity, pressure, density, and temperature, as functions of space and time.*

Unit-I: Six governing equations of fluid motion, crocco-vazsonyl equation. Propagation of small disturbances in a gas. mach number. Dynamics similarity of two flows. Circulation theorem. Permanence of irrotational motion. Bernoulli's integral for steady isentropic and irrotational motion.

Unit-II: Polytropic gas. Critical speed. Equation satisfied velocity potential and stream functions. Prandtl-Mayer fluid past a convex corner. Steady flow through a De Level nozzle. Normal and oblique shock wave shock polar diagram one dimensional similarity folw.

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

Unit-IV: Legendre 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 a vortex Karman-Tsien approximation.

Unit-V: Two dimensional steady flow : Riemann invarience. Method of characteristic. Transonic flow. Law transonic similarity. Euler's-Tricomi equation and its fundamental solution. Hypersonic flow.

** Any other advancement in this field may be incorporated.

References:

1. Hydrodynamics –A.S.Ramsay(Bell)
2. Hydrodynamics – H. Lamb(Cambridge)
3. Fluid mechanics – L.D.Landou and E.M.Lifchiz(Pergamon),1959
4. Theoritical hydrodynamics –L.M.Thomson
5. Theoritical aerodynamics –I.M.Milne-Thomson;Macmillan, 1958
6. Introduction to the theory of compressible flow –Shih-I.Pai; Van Nostrand, 1959
7. Inviscid gas dynamics – P.Niyogi, Mcmillan, 1975(india)
8. Gas dynamics – K.Oswatitsch(english tr.) academic press, 1956

Course Title: Project Work

Course Code: MATH-407E

Full Marks: 100 (End Term: 70 + Internal: 30)

Credit: 4

Objectives: *Project work, which is also a discipline specific elective course, is important as gives a glimpse of research work to the aspiring students. This in fact encourages them to opt for high quality research in the future.*

Here students will have to prepare project papers/reports under supervisors and present their work through power point presentation at the time of internal as well as end term examination. They will have to submit the hard copies of their works. The works may be survey-based report or may be a new finding or may be solving new problems from any standard text. Students will have to finalize their project topics in consultation with their respective supervisors.

Course Title: Foundation Course of Advanced Computer Skills
Course Code: MATH-105COE
Full Marks: 100 (End Term: 70 [Theory: 50, Practical: 20] + Internal: 30[Theory: 15, Practical: 15]))
Credit: 4

Objectives: *A computer is a machine that can be instructed to carry out sequences of arithmetic or logical operations automatically via computer programming. Modern computers have the ability to follow generalized sets of operations, called programs. These programs enable computers to perform an extremely wide range of tasks. A "complete" computer including the hardware, the operating system (main software), and peripheral equipment required and used for "full" operation can be referred to as a computer system. This term may as well be used for a group of computers that are connected and work together, in particular a computer network or computer cluster. Computers are used as control systems for a wide variety of industrial and consumer devices. This includes simple special purpose devices like microwave ovens and remote controls, factory devices such as industrial robots and computer-aided design, and also general purpose devices like personal computers and mobile devices such as smart phones. The Internet is run on computers and it connects hundreds of millions of other computers and their users.*

Unit-I: MS Office and Google Apps

MS Word: Operations of MS Word, Various features of MS Word.
MS Excel: Operations of MS Excel, Various functions of Excel, Coding in Excel, Preparation of Excel Data sheet, Graphics.
MS PowerPoint: Preparation of presentation slides using various features of Power Point.
Google Apps: Using various Google Apps like Google Form, Google Sheet, Google Slides, Google Docs, Webpage designing etc.

Unit-II:Advanced C-Programming (Part-I)

Arrays: One and two dimensional; Multi dimensional arrays; Strings or Character Arrays; String handling functions; Table of Strings; Array operations; Arithmetic operations on strings.
User Defined Functions: Definition of Functions; Return Values and their Types; Function Calls; Function Declaration; Category of Functions; No Arguments and No Return Values; Arguments but No Return Values; Arguments with Return Values; No Arguments but Returns a Value; Functions that Return Multiple Values; Nesting of Functions; Recursion; Passing Arrays to Functions; Passing Strings to Functions; The Scope, Visibility and Lifetime of Variables.

Unit-III:Advanced C-Programming (Part-II)

Pointers: Understanding Pointers, Accessing the Address of a Variable, Declaring Pointer Variables, Initialization of Pointer Variables, Accessing a Variable through its Pointer, Chain of Pointers, Pointer, Expressions, Pointer Increments and Scale Factor, Pointers and Arrays, Pointers and Character Strings, Array of Pointers, Pointers as Function Arguments, Functions Returning Pointers, Pointers to Functions.

Unit-IV: MATLAB(Part-I)

Basics: Creation, Saving and Execution of script files; Arrays of numbers and operations on them; 2D and 3D Plot; Matrices; Functions; Matrix manipulations; Arithmetic, Relational, Logical operations; Elementary math functions; Inline functions; If statement; Looping (for, while).

Unit-V:MATLAB (Part-II)

ODE suite: Coding using ODE45, ODE23, ODE19s; Phase Portraits; Time series analysis; p-Plane analysis.

** Any other advancement in this field may be incorporated.

References:

1. *E. Balaguruswamy* ,**Programming with ANSI-C**, Tata McGraw Hill.
2. *Rudra Pratap*, **Getting Started with MATLAB**, Oxford.

Course Title: National Service Scheme (NSS)

Course Code: NSS-201OE

Full Marks: 100 (End Term: 70 [Theory: 40, Practical: 30] + Internal: 30[Theory: 15, Practical: 15])

Objectives: *The symbol for the NSS has been based on the giant Rath Wheel of the world-famous Konark Sun Temple (The Black Pagoda) situated in Odisha, India. The wheel portrays the cycle of creation, preservation and release. It signifies the movement in life across time and space, the symbol thus stands for continuity as well as change and implies the continuous striving of NSS for social change. The eight bars in the wheel represent 24 hours of a day. The red colour indicates that the volunteer is full of young blood that is lively, active, energetic and full of high spirit. The navy blue colour indicates the cosmos of which the NSS is tiny part, ready to contribute its share for the welfare of the mankind. It stands for continuity as well as change and implies the continuous striving of NSS. The programme aims to instilling the idea of social welfare in students, and to provide service to society without bias. NSS volunteers work to ensure that everyone who is needy gets help to enhance their standard of living and lead a life of dignity. In doing so, volunteers learn from people in villages how to lead a good life despite a scarcity of resources. It also provides help in natural and man-made disasters by providing food, clothing and first aid to the disaster's victims.*

Group-A: Theory

Unit-I: Introduction and basic Concepts:
History, philosophy, aims and objectives of NSS, Emblem, flag, motto, song badge etc., Organizational structure, roles and responsibilities of various NSS functionaries, Basis of adoption of village/slums, Methodology of conducting survey, Maintenance of the diary, Concept of regular activities, Special camping, Day camps, Indian tradition of volunteerism, Needs, Importance, Motivation and Constraints of volunteerism, Shramdan as a part of volunterism.

Unit-II: Cognitive Youth Development:
Definition, profile of youth, categories of youth, Issues, challenges and opportunities for youth, Youth as an agent of social change, Meaning and types of leadership, Qualities of good leaders, traits of leadership, Importance and role of youth leadership, National Youth Policy, Healthy Lifestyles, HIV-AIDS, Drugs, Substance abuse, COVID-19, Home nursing, First Aid, Awareness against Anti-Ragging, Positive thinking, Self confidence and self esteem, Setting life goals and working to achieve them, Stress and Time management.

Unit-III: Society and Community Mobilization:
Concept of community and society, Mapping community stakeholders, Designing the message in the context of the problem and culture of the community, Identifying methods of mobilization, Youth-adult partnership, Human values, Gender sensitization, Human rights, Fundamental Rights and Duties, RTI, Cyber Crime and its prevention, Sociological and Psychological factors influencing Youth Crime, Basic features of constitution of India.

Unit-IV: Environmental Issues:
Environment conservation, Enrichment and Sustainability, Climate change, Waste management, Natural resource management (Rain water harvesting, energy conservation, waste land development, soil conservations and afforestation), Disaster Management, Classification of disasters, Role of youth in Disaster Management, Safe drinking water, water borne diseases and sanitation, Swachh Bharat Abhiyan.

Unit-V: Youth and Yoga:
India History, Philosophy and concept of Yoga, Myths and misconceptions about yoga, Different yoga traditions and their impacts, Yoga as a preventive, promotive and curative method, Yoga as a tool for healthy lifestyle.

Group-B: Practical

Project Work:
Project planning, Project implementation, Project monitoring, Project evaluation, Impact assessment, Collection and analysis of data, Preparation of reports/documentation, Dissemination of documents/reports.

Field Work:
Cleanliness Drive, Awareness Campaigns, Conducting surveys, Workshop/Seminars on personality development and improvement of communication skills etc.

** Any other advancement in this field may be incorporated.