Department of Mathematics
Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

Institute Vision

To become a Globally Recognized Academic Institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the National needs.

Institute Mission

- To educate students at Undergraduate, Post Graduate Doctoral and Post-Doctoral levels to perform challenging engineering and managerial jobs in industry.
- To provide excellent research and development facilities to take up Ph.D. programmes and research projects.
- To develop effective teaching and learning skills and state of art research potential of the faculty.
- To build national capabilities in technology, education and research in emerging areas.
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society.

Department Vision

- To become a globally recognized centre of excellence in teaching and research, producing excellent academicians, professionals and innovators who can positively contribute towards the society.

Department Mission

- Imparting strong fundamental concepts to students in the field of Mathematical Sciences and motivate them towards innovative and emerging areas of research.
- Creation of compatible environment and provide sufficient research facilities for undertaking quality research to achieve global recognition.

Program Educational Objectives (PEO)

1. To impart conceptual knowledge of Mathematical Sciences for formulating and analyzing the real world problems with futuristic approach.
2. To equip the students sufficiently in both analytical and computational skills in Mathematical Sciences.
3. To develop a competitive attitude for building a strong academic - industrial collaboration, with focus on continuous learning skills.
4. To nurture and nourish strong communication and interpersonal skills for working in a team with high moral and ethical values.

Programme Outcomes(PO)

A graduate of this program are expected to:

1	gain sound knowledge on fundamental principles and concepts of Mathematics with their applications related to Industrial, Engineering, Biological and Ecological problems.
2	exhibit in depth the analytical and critical thinking to identify, formulate and solve real world problems of science and engineering.
3	be proficient in arriving at innovative solution to a problem with due considerations to society and environment.
4	be capable of undertaking suitable experiments/research methods while solving the real life problem and would arrive at valid conclusions based on appropriate interpretations of data and experimental results.
5	exhibit understanding of societal and environmental issues (health, legal, safety, cultural etc) relevant to professional practice and demonstrate through actions, the need for sustainable development
6	be committed to professional ethics, responsibilities and economic, environmental, societal and political norms.
7	demonstrate appropriate inter-personal skills to function effectively as an individual, as a member or as a leader of a team and in a multi-disciplinary setting.
8	develop written and oral communications skills in order to effectively communicate design, analysis and research results.
9	be able to acquire competent positions in industry and academia as well.
10	be able to acquire lifelong learning and continuous professional development.
11	be conscious of financial aspects of all professional activities and shall be able to undertake projects with appropriate management control and control on cost and time.
12	recognize the need for continuous learning and will prepare himself/ herself appropriately for his/her all-round development throughout the professional career.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓		
Quiz (s)	✓	✓	✓		
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 501
Course title: Functional Analysis
Pre-requisite(s): Basics of Real Analysis and Linear Algebra
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, 1 Tutorials
Class: MSc
Semester / Level: III/5
Branch: Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	Extension of concepts of Real analysis and Linear Algebra
2.	Different Linear Spaces and their applications
3.	Extension of Eigen values and Eigen functions in Banach Spaces and Hilbert spaces.
4.	Concepts of Bounded Linear operators on Hilbert spaces
5	Concepts on Hilbert Space

Course Outcomes: After the completion of this course, students will be able to

CO1.	Apply the theory of functional analysis in the qualitative study of different mathematical models in Biological and Ecological systems and different engineering problems.
CO2.	This will help the students to study the stability theory of Differential equations and difference equations
CO3	Understand the concept of topology in real world problems.
CO4.	Applications of topological approach in the study of solutions of Difference Equations in different boundary value problems arising in Biological and Ecological systems and different engineering problems.
CO5	Use of topological concepts in Architecture Engineering.

Syllabus

MA501 **Functional Analysis** **3-1-0-4**

Module I

Preliminaries: Relation on a set, function, equivalence relation, partial order relation, partial order set, maximal, totally ordered set, Zorn's lemma, Axiom of choice.

Introduction to linear spaces, linear maps, convex, span of a set, linearly dependent and independent set, finite and infinite dimensional linear spaces, quotient spaces, linear map, zero space, null space, zero map, linear functional, hyperspace, hyperplane.

Metric space and continuous functions: Definition and examples, Holder inequality, Minkowski inequality, open sets, separable metric spaces, Cauchy sequence, complete metric space, Baire theorem, Compactness, Heine-Borel theorem, Continuity of functions, Uryshon's lemma, Tietze's Extension theorem, Ascolli's theorem. [10L]

Module II

Normed Linear Space: Normed linear spaces over R and C, Definitions and examples including N/M where M is a closed subspace of N and $||x+M||=\inf\{||x+M: x \epsilon M\}$. With normed linear spaces N and N' over same scalars: N→N' continuous bounded linear maps and equivalent formulations of continuous linear maps. Norm in B(N,N') and equivalent descriptions. N* (dual of N) and functionals on N, equivalence of norms, special features of finite dimensional normed linear spaces, convexity, Riesz lemma, Hahn-Banach extension theorem and its applications, Natural embedding of N and N*, to find l_p^*, C_0^* and C*[0,1]. [10L]

Module III

Banach Space: Definition and examples together with N/M and B(N,N'), Open mapping theorem, Projection on Banach space, closed Graph theorem, Uniform bounded theorem, conjugate of an operator on a normed linear space, Properties of T→T* maps. [7L]

Module IV

Hilbert spaces: Inner product spaces, Polarization identity, Jordan Von-Neumann theorem, Parallelogram law, Schwarz's inequality. Hilbert space, orthonormal set, Pythagoras theorem, The Gram-Schmidt orthogonalization theorem, Bessel inequality, Orthonormal basis, Fourier expansion and Parseval's formulae.

Projection theorem, Riesz Representation theorem, unique Hanh- Banach extension theorem. [8L]

Module V

Operators on a Hilbert space : Adjoint of an operator on a Hilbert space (existence and uniqueness), properties of Adjoint, Self Adjoint operator and its characteristics and positive operator, real and imaginary parts of an operator: Normal operator and Unitary operator together with their characterization, Projection operator, Invariance and Reducibility, Orthogonal projections and sum of projections on closed subspaces of H, Matrix of an operator on a finite dimensional H, Spectral theorem for finite dimensional H. [10L]

Text Books:

1. B. V. Limaye, Functional Analysis, Revised Third Edition, New Age International Ltd., New Delhi.

Reference Books:

1. Erwin Kreyszig, Introductory functional analysis with applications, John Wiley and Sons, New York, 1978.
2. M.T. Nair, Functional Analysis: A first course,PHI learning pvt. Ltd. 2010.
3. J. B. Conway, A course in Functional Analysis, Springer Verlag, New York, 1985.
4. P. R. Halmos, A Hilbert space problem book, Van Nostrand, Princeton, New Jersey, 1967.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	2	1	2	2	2	2	3	3
CO2	3	3	2	2	2	1	2	2	2	2	3	3
CO3	3	2	1	1	1	1	2	1	2	2	3	2
CO4	3	2	1	2	1	1	2	1	2	2	3	2
CO5	3	2	2	2	1	1	2	1	2	2	2	3

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 502
Course title: Number Theory
Pre-requisite(s): Modern Algebra, Linear Algebra
Co- requisite(s): ---NIL
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, 1 Tutorials
Class: MSc.
Semester / Level: III/ 5
Branch: Mathematics
Name of Teacher:

Course Objectives : This course enables the students to

1.	identify and apply various properties of integers including factorization, the division algorithm, and greatest common divisors. This course also enables students to identify certain number theoretic functions and their properties.
2.	understand the concept of a congruence, Chinese Remainder Theorem, Euler's Theorem, Fermat's Theorem. It also enables students to solve certain types of Diophantine equations, Pelle's equation and its relation to continued fraction
3.	Understand the concept of primitive roots for primes, Legendre Symbol, Jacobi Symbol
4.	identify how number theory is related to cryptography

Course Outcomes : After the completion of this course, students will be able to

CO 1	apply the number theory to specific research problems in mathematics or in other fields.
CO 2	Use Fermat's, Euler's and Chinese remainder theorems to solve congruence equations arise in various research problems
CO 3	solve Pell's equation with the use of continued fraction, and learn how to find primitive roots
CO 4	use Primality test and factorization algorithm to factor large composite numbers.
CO 5	learn how to apply number theory in various research problems arising in cryptography.

Syllabus

MA502 Number Theory 3-1-0-4

Module I

Divisibility: basic definition, properties, prime numbers, some results on distribution of primes, Division algorithm, greatest common divisor, Euclid's Lemma, Euclidean Algorithm, fundamental theorem of arithmetic, the greatest common divisor of more than two numbers. Arithmetic functions and properties: Mobius function $\mu(n)$, Euler's totient function $\phi(n), \sigma(n), \tau(n), d(n)$ Mobius inversion formula. [9L]

Module II

Congruences: definitions and basic properties, residue classes, Reduced residue classes, complete and Reduced residue systems, Fermat's little Theorem, Euler's Theorem, Wilson's Theorem, Algebraic congruences and roots. Linear congruences, Chinese Remainder theorem and its applications. Polynomial congruences: Meaning of "divisor" modulo n, root and divisor. Theorem of Lagrange on polynomial congruence modulo p. Application of Taylor's series for polynomial congruence modulo prime power. Primitive roots: A property of reduced residue system belonging to an exponent modulo m, primitive roots, existence and number of primitive roots of a prime. [10L]

Module III

Quadratic Number fields: Integers, Units, Primes and irreducible elements, Failure of unique factorization, simple continued fractions: finite and infinite, linear Diophantine equations, Pell's equation via simple continued fraction. [9L]

Module IV

Primality Testing and factorization algorithms, Pseudo-primes, Fermat's pseudo-primes, Pollard's rho method for factorization. Euler's criterion, quadratic residue, Legendre and Jacobi Symbol and their properties, Evaluation of (-1/p) and (2/p), Gauss's Lemma, Quadratic reciprocity law. [9L]

Module V

Public Key cryptography, Diffie-Hellmann key exchange, Discrete logarithm-based cryptosystems, RSA crypto-system, Rabin crypto-system, Knapsack crypto-system, Paillier crypto-system, Introduction to elliptic curves: Group structure, Rational points on elliptic curves, Elliptic Curve Cryptography: applications in cryptography and factorization. [8L]

Text Books

1. Apostal T.M.: Introduction to Analytic Number Theory, Springer-Verlag
2. Burton D.M.: Elementary Number Theory, Tata McGraw-Hill Publishing Company
3. Douglas R. Stinson: Cryptography Theory and Practice, Chapman and Hall/CRC

Reference Books

1. Niven, Zuckerman H.S. and Montgomery H.L.: An Introduction to the Theory of Numbers, Wiley,
2. Hardy G.H and Wright E.M.: An Introduction to the Theory of Numbers, Fifth Ed., Oxford University Press.
3. George E. Andrews: Number Theory, HPC.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
End Semester Examination	√	√	√	√	√
Quiz (s)	√	√	√	√	√
Assignment	√	√	√	√	√
Seminar	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	1	1	1	3	3	3	2	2
CO2	3	3	3	3	1	1	1	3	3	3	2	2
CO3	3	3	3	3	1	1	1	3	3	3	2	2
CO4	3	3	3	3	1	1	1	3	3	3	2	2
CO5	3	3	3	3	1	1	1	3	3	3	2	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 510
Course title: Advanced Differential Equations
Pre-requisite(s):ordinary and partial differential equations
Co- requisite(s): ---
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 3 lectures.
Class: M.Sc
Semester / Level:III / PG
Branch: Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	existence and uniqueness theorem for first order ODEs, stability, adjoint and self-adjoint differential equations, Sturm-Liouville problem,
2.	Non-linear partial differential equations, Charpit's and Jacobi's methods, Cauchy's method of characteristics, Higher order linear partial differential equations with constant coefficients,
3.	Classification and canonical transformation of second order linear partial differential equations. Method of separation of variables for solving hyperbolic, parabolic.
4.	Dirichlet, Neumann, Cauchy boundary conditions. Dirichlet and Neumann problems for a rectangle, theory of Green's function for Laplace equation.

Course Outcomes: After the completion of this course, students will be able to

CO1	solve differential equation problems in the field of Industrial Organisation Engineering.
CO2	competence in solving applied linear and nonlinear problems
CO3	solve the problems choosing the most suitable method
CO4	solve the partial differential equations with boundary conditions and initial conditions
CO5	handle Dirichlet, Neumann, Cauchy boundary conditions and solve Dirichlet and Neumann problems for a rectangle, theory of Green's function for Laplace equation.

Syllabus

MA510 **<u>Advanced Differential Equations</u>** **3-0-0-3**

Module I

Existence and uniqueness of solution of initial value problems for first order ODEs, singular solutions of first order ODEs, system of first order ODEs . Introduction, definition of stability, linear systems, almost linear systems, conditional stability. Adjoint and Self-Adjoint differential equations, Sturm-Liouville problem, eigenvalues and eigenfunctions, singular Sturm-Liouville problem, orthogonally of eigenfunctions and eigenfunctions expansion. **[8L]**

Module II

Non-linear partial differential equations, compatible system of first order equations, Charpit's and Jacobi's methods, Cauchy’s method of characteristics, Higher order linear homogenous and non-homogenous partial differential equations with constant coefficients. Classification and canonical transformation of second order linear partial differential equations. **[8L]**

Module III

Method of separation of variables for linear partial differential equations; Hyperbolic Equations: D’Alembert’s solution, vibrations of an infinite string and a semi-infinite string. Vibrations of string of finite length (separation method), Riemann’s method. **[8L]**

Module IV

Parabolic Equations: Method of separation of variables:heat equation, heat conduction problem for an infinite rod, a finite rod, Duhamel’s principle for parabolic equations. **[8L]**

Module V

Elliptic Equations: Boundary value problems: Dirichlet’s, Neumann, Cauchy boundary conditions. Maximum and minimum principles, Dirichlet’s and Neumann problems for a rectangle (separation of variables), theory of Green’s function for Laplace equation. **[8L]**

Text Book:

1. I. N. Sneddon: Elements of Partial Differential Equations, McGraw-Hill
2. Richard C. DiPrima and William E. Boyce: Ordinary Differential Equations and Boundary Value Problems, John Willey
3. T. Amaranath: An Elementry Course in Partial differential equations, Narosa Publishing House
4. S. L. Ross: Differential Equations, Wiley
5. K. Sankara Rao: Introduction to Partial Differential Equations, PHI Learning

Reference books:

1. M.D. Raisinghania: Advanced Differential Equations, S. Chand & Co.
2. Walter A. Strauss: An Introduction to Partial Differential Equation, Wiley

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
End Semester Examination	√	√	√	√	√
Quiz (s)	√	√	√	√	√
Assignment	√	√	√	√	√
Seminar	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	1	1	1	3	3	3	2	2
CO2	3	3	3	3	1	1	1	3	3	3	2	2
CO3	3	3	3	3	1	1	1	3	3	3	2	2
CO4	3	3	3	3	1	1	1	3	3	3	2	2
CO5	3	3	3	3	1	1	1	3	3	3	2	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

Program Electives (PE)

COURSE INFORMATION SHEET

Course code: MA 405
Course title: Mathematical Modeling
Pre-requisite(s): MA 106, MA 201, MA301, MA311
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc/ MSc
Semester/level: VII / 4
Branch: Mathematics and Computing/ Mathematics
Name of the Faculty:

Course Objectives : This course enables the students to get the detailed idea about:

1.	models, properties of models, model classification and characterization, steps in building mathematical models.
2.	analytic methods of model fitting
3.	Discrete Probabilistic Modeling
4.	Modeling with a Differential Equations
5	Simulation Modeling – Discrete-Evvnt Simulation, Continuous Simulation, Monte-Carlo simulation

Course Outcomes: After completion of the course, the learners will be able to:

CO1.	learn different approach of mathematical modelling
CO2	perform a task of model fitting using different mathematical methods in least expensive ways.
CO3.	get an understanding of solving and validating proposed mathematical models with different physical behavior of the problems.
CO4.	apply the principles of mathematical modelling to solve a variety of practical problems in sciences and engineering.
CO5.	equip the students with standard concepts and tools at an intermediate to advanced level that will serve them well towards tackling more advanced level of mathematics

Syllabus

MA405 Mathematical Modeling 3-0-0-3

Module I

Introduction Models, reality, Properties of models, model classification and characterization, steps in building mathematical models, sources of errors, dimensional analysis. Modeling using Proportionality, Modeling using Geometric similarity; graphs of a functions as models. [8L]

Module II

Model Fitting – Fitting models to data graphically, Analytic methods of model fitting, Applying the least square criterion, Experimental Modeling – High order polynomial models, Cubic Spline models. [8L]

Module III

Discrete Probabilistic Modeling –Probabilistic modeling with discrete system; Modeling components & System Reliability; Linear Regression. Discrete Optimization Modeling – Linear Programming – Geometric solutions, Algebraic Solutions, Simplex Method and Sensitivity Analysis [8L]

Module IV

Modeling with a Differential Equations – Population Growth, Graphical solutions of autonomous differential equations, numerical approximation methods-- Euler's Method and R.K. Method. Modeling with systems of Differential Equations – Predator Prey Model, Epidemic models, Euler's method for systems of Differential equations. [8L]

Module V

Simulation Modeling – Discrete-Evvnt Simulation, Generating random numbers; Simulating probabilistic behavior; Simulation of Inventory model and Queueing Models using C program. Other Types of simulation—Continuous Simulation, Monte-Carlo simulation. Advantages, disadvantages and pitfalls of simulation Case Study: Case Studies for various aspects of Modeling to be done. [8L]

Text Books:

1. Frank R. Giordano, Mawrice D Weir, William P. Fox, A first course in Mathematical Modeling 3rd ed3 2003. Thomson Brooks/Cole, Vikas Publishing House (P) Ltd.
2. J.D. Murray, Mathematical Biology – I, 3rd ed2 2004, Springer International Edition.
3. J.N. Kapoor, Mathematical Models in Biology and Medicine, 1985, East West Press, N. Delhi

Reference Book:

4. Sannon R.E, System Simulation: The Art and Science, 1975, Prentice Hall, U.S.A
5. Simulation Modeling and Analysis-Averill M. Law & W. David kelton;Tata McGrawHill

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA406
Course title: Fuzzy Mathematical Programming
Pre-requisite(s): MA314
Credits:L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc /MSc
Semester: VII/ 4
Branch: Mathematics and Computing/ Mathematics
Course Co-ordinator:

Course Description:

1	Fuzzy Set Theory: Basic terminology and definition. Membership Function. Examples to generate membership functions. Distance approach, True- valued approach, payoff function.
2	Fuzzy Decision and Fuzzy Operators. Fuzzy Arithmetic:Addition of Fuzzy Numbers, Subtraction of Fuzzy Numbers, Multiplication of Fuzzy Numbers,Division of Fuzzy Numbers,Triangular and Trapezoidal Fuzzy Numbers. Fuzzy Linear programming Models:Linear Programming Problem with Fuzzy Resources: Verdegay's Approach. Werner's approach..
3	Linear Programming with Fuzzy Resources and objective. Zimmermann's Approach.. A regional resource allocation problem. Chana's Approach. An optimal system design Problem.
4	Linear Programming with Fuzzy parameters in the objective function. Interactive Fuzzy Linear Programming, Introduction, Discussion of zimmermann's, Werners'sChanas's and Verdegay's Approaches. Interactive Fuzzy Linear Programming - I. Problem Setting The Algorithm of IFLP-I. Interactive Fuzzy Linear Programming - II.The Algorithm of IFLP-II
5	Linear Programming with Imprecise Coefficients. Linear Programming with Imprecise Objective. Coefficients and Fuzzy Resources.

Course Outcomes: After the completion of the course, the students will be able to:

CO1	learn about various terminologies important in fuzzy mathematicalprogramming.
CO2	learn about Fuzzy Decision and Fuzzy Operators in fuzzy mathematical programming.
CO3	learn about Linear Programming with Fuzzy Resources and objective
CO4	learn Linear Programming with Fuzzy parameters in the objective function
CO5	learn about Linear Programming with Imprecise Coefficients.

Syllabus

MA 406 FUZZY MATHEMATICAL PROGRAMMING 3-0-0-3

MODULE I:

Fuzzy Set Theory:Basic Terminlogy and Definition.Support,α-level set,normality,convexity and Concavity,Extension Principle,Compatibility of extension principle with α-cuts,relation,Decomposability, Decomposition Theorem.Basic Fuzzy operations:Inclusion,Equality,Complementation,Intersection,union,AlgebraicProduct,Algebraic Sum,Difference.Membership Function.A survey of functional forms.Examples to generate membership functions.:Distance approach,True- valued approach,payoff function. [8L]

MODULE II

Fuzzy Decision and Fuzzy Operators:Fuzzy Decision,Max-Min operator,compensatory operators.Fuzzy Arithmetic:Addition of Fuzzy Numbers,Subtraction of Fuzzy Numbers,Multiplication of Fuzzy Numbers,Division of Fuzzy Numbers,Triangular and Trapezoidal Fuzzy Numbers.Fuzzy Linear programming Models:Linear Programming Problem with Fuzzy Resources:Verdegay's Approach.The knox Production Mix selection Problem.A tranportation Problem.Werner's approach.The Knox Production-Mix selection Problem. An Air Pollution Regulation Problem. [8L]

MODULE III:

Linear Programming with Fuzzy Resources and objective. Zimmermann's Approach. The knox Production-Mix Selection Problem. A regional resource allocation problem. Chana's Approach. An optimal system design Problem. An aggregate Production Planning Problem. [8L]

MODULE IV:

Linear Programming with Fuzzy parameters in the objective function. Linear Programming with all fuzzy coefficients. A Production scheduling problem. Interactive Fuzzy Linear Programming, Introduction, Discussion of zimmermann's, Werners'sChanas's and Verdegay's Approaches. Interactive Fuzzy Linear Programming - I. Problem Setting The Algorithm of IFLP-I. Example: The Knox Production-Mix. Selection Problem.Interactive Fuzzy Linear Programming - II.The Algorithm of IFLP-II. [8L]

MODULE V:

Linear Programming with Imprecise Coefficients. Lai and Hwang's Approach. Buckley's Approach. Example: A Feed Mix (Diet) Problem. Negi's Approach. Fuller's Approach . Other Problems . Linear Programming with Imprecise Objective. Coefficients and Fuzzy Resources . Example: A Bank Hedging Decision Problem. [8L]

Text Books

1. **Young-Jou Lai -Lai Hwang**, Fuzzy Mathematical Programming: Methods and Applications, Springer-Verlag Berlin Heidelberg,1992.

2. **H.-J. Zimmermann**, Fuzzy Set Theory and Its Applications, Springer Science+Business Media, LLC, Fourth Edition,2001.

Reference Book

1. **Jagdeep Kaur and Amit Kumar**, An introduction to Fuzzy Linear Programming Problems: Theory, Methods and Applications (Studies in Fuzziness and Soft Computing),1st ed.2016Edition.

2. **Klir,G.J. and Yuan, Bo.** *Fuzzy sets and Fuzzy Logic, Theory and Applications*, Prentice Hall of India, 2002.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	√	√	√	√	√
End Semester Examination	√	√	√	√	√
Quiz (s)	√	√	√	√	√
Assignment	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	2	3	3	3	3	3
CO2	3	3	3	3	3	2	2	2		3	3	3
CO3	3	3	3	3	3	2	3	3	3	3	3	3
CO4	3	3	3	3	3	2	3	3	3	3	3	3
CO5	3	3	3	3	3	2	3	3	3	3	3	3

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA407
Course title: Survey Sampling
Pre-requisite(s): Basics of Probability and Statistics
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc/MSc
Semester/level: VII / 4
Branch: Mathematics and Computing/ Mathematics
Name of the Faculty:

Course Objectives : This course will enable the students to understand:

1.	Sampling unit, Sampling frame and Sampling design, along with the various methods of primary data collection
2.	Sampling and Non-sampling errors
3.	Simple Random Sampling, Stratified Sampling, and various others Probability Sampling Designs
4.	Methods of Estimation of Population Parameters (such as Population Mean and Population Variance)
5.	Two-phase (or Double) Sampling and estimation of optimum sample sizes using Cost Function Analysis
6.	Probability Proportional to Size (PPS) sampling, Midzuno Sampling design, Ordered and unordered estimators

Course Outcomes : After completion of the course, the students will be able to:

CO1	Differentiate between Sampling and Non-sampling errors.
CO2	Gain an understanding of various methods of primary data collection.
CO3	Gain an understanding of various Probability Sampling Designs.
CO4	Describe the various procedures for Estimation of Population Parameters (such as Population Mean and Population Variance).
CO5	Gain an understanding of Two-phase Sampling and demonstrate the procedure for estimation of optimum sample sizes using Cost Function Analysis.

Syllabus

MA407 **Survey Sampling** 3-0-0-3

Module I

Concept of Population and Sample, Primary and Secondary data, Methods of Collecting Primary data, Sampling unit, Sampling frame, Sampling design, Census and Sample Surveys, Sampling and Non-sampling errors. [8L]

Module II

Simple Random Sampling, Stratified Sampling, Advantages of Stratification, Allocation of sample size in different strata, Systematic Sampling, Cluster Sampling, Two-stage sampling. [8L]

Module III

Concept of Study variable and Auxiliary variable, Estimation of population mean and variance using Ratio, Product and Regression Methods of Estimation, Methods for obtaining unbiased estimators. [8L]

Module IV

Concept of Two-phase (or Double) Sampling, Double Sampling for Ratio and Regression Estimators, Cost function Analysis. [8L]

Module V

Probability Proportional to Size (PPS) sampling, Inclusion Probabilities, Horvitz-Thompson estimator, Yates-Grundy form, Midzuno Sampling design, Ordered and Unordered estimators. [8L]

Text Books:

1. W.G. Cochran: Sampling Techniques, John Wiley and Sons, 3rd Edition, 1977.
2. P.V. Sukhatme, B.V. Sukhatme, S. Sukhatme and C. Ashok: Sampling Theory of Surveys with Applications, Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi, 1984.
3. D. Singh and F.S. Choudhary: Theory and Analysis of Sample Survey Designs, Wiley Eastern, 1986.

Reference Books:

1. M.N. Murthy: Sampling Theory and Methods, Statistical Publishing Society, 1979.
2. S.C. Gupta and V.K. Kapoor: Fundamentals of Applied Statistics, Sultan Chand and Sons, 1994.
3. S. Singh: Advanced Sampling Theory with Applications, Kluwer Academic Publishers, 2004.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 408
Course title: Theory of Elasticity
Pre-requisite(s): Nil
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc/ MSc
Semester / Level: VII / 4
Branch: Mathematics and Computing/Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand:

1.	The classical theory of linear elasticity for two and three-dimensional state of stress, Tensorial character of stress and strain.
2.	The solutions for selected problems of Elasticity in rectangular and polar coordinate as well as torsion of prismatic bars.
3.	The plane problems, Problems of Axi-symmetric stress distribution; Problems in Polar coordinates-simple radial stress distribution and problems on wedges.
4.	The semi-inverse and inverse methods, Torsion of non-circular sections, Strain energy method-strain energy density, and Complex variable technique: complex stress functions.

Course Outcomes : After the completion of this course, students will be able to:

CO1	analyze the motion of particles in elastic medium.
CO2	understand the deformation of elastic body.
CO3	determine the motion of elastic body in different coordinates system.
CO4	to find the solution of some engineering problem like strips, beams, membrane and plate problems.
CO5	demonstrate a depth of understanding in advanced mathematical topics which will serve them well towards tackling real world problems of science and engineering.

Syllabus

MA408 **Theory of Elasticity** **3-0-0-3**

Module I

Stress and Strain components at a point; Equations of equilibrium; Stress-Strain relationships, Generalized Hooke's Law; Strain compatibility relations; Boundary conditions; Uniqueness theorem and Superposition principles; other theorems-double suffix notation is adopted. [8L]

Module II

Transformation of stress and strain at a point, their tensorial character; characteristic equations of stress and strain tensors and invariants- octahedral shear stress. [8L]

Module III

Plane problems of elasticity in rectangular and polar coordinates-stress function approach; Solution by Polynomials; Displacements in simple cases; Problems of Axi-symmetric stress distribution; Problems in Polar coordinates-simple radial stress distribution and problems on wedges. [8L]

Module IV

Semi-inverse and inverse methods; Torsion of non-circular sections. Strain energy method – strain energy density; Variational principle. Applications to strips, beams, membrane and plate problems. [8L]

Module V

Complex variable technique-complex stress functions, stresses and displacements in terms of complex potentials, boundary conditions. [8L]

Text Books:

1. Timoshenko S., Theory of Elasticity, McGraw-Hill Companies, (1970).
2. Timoshenko S. and Goodier J.N., Theory of Elasticity, McGraw-Hill, Inc., New York, (1951).

Reference Books:

1. William S. Slaughter, The Linearized theory of elasticity, (2002).
2. Sokolonikoff I.S., The Mathematical Theory of Elasticity, McGraw-Hill, New York, (1956).
3. Sadhu Singh, Theory of Elasticity, Khanna Publishers, (2003).
4. Chow and Pagano, Elasticity for Engineers.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

<u>Course Outcome (CO) Attainment Assessment tools & Evaluation procedure</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of Course Outcomes onto Program Outcomes</u>

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 410
Course title: Differential Geometry
Pre-requisite(s): Vector Analysis
Co- requisite(s): ---
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc/MSc
Semester / Level: VII/4
Branch: Mathematics and Computing/Mathematics
Name of Teacher:

Course Objectives

This course enables the students to understand

1.	differential geometry of curves, their fundamental properties like torsion, curvature etc. along with their different forms
2.	differential geometry of surfaces, their different properties, along with their different forms
3.	curvilinear coordinates on a surface and fundamental magnitudes on a surface
4.	different forms of curves and surfaces, along with their diverse properties through the use of differential calculus

Course Outcomes

After the completion of this course, students will be able to

CO1.	develop different properties associated with curves and surfaces
CO2	use differential forms to perform calculus on curves and surfaces
CO3.	apply the theory of differential geometry to specific research problems in mathematics or other fields.
CO4.	gain an understanding to solve problems with the use of differential geometry to diverse situations in mathematical contexts
CO5.	demonstrate a depth of understanding in advanced mathematical topics in relation to geometry of curves and surfaces

Syllabus

MA410 Differential Geometry 3-0-0-3

A) Geometry of Curves

Module I
Curves, curves in n- dimensional space with examples, plane curve, space curve, properties of plane curve and space curve, arc-length, parameterization of curves, regular curve, tangent, principal normal, binormal, curvature, torsion, screw curvature, TNB frame, fundamental planes, Serret-Frenet formulae. [8L]

Module II
Intrinsic equations, existence and uniqueness theorems, contact between curves and surfaces, osculating plane, Locus of centre of curvature, spherical curvature, osculating sphere, spherical indicatrix of tangent, normal and binormal, involutes, evolutes, Bertrand curves. [8L]

B) Geometry of Surfaces

Module III
Surfaces, different forms of surfaces, smooth surface, tangent plane, normal line.
Length of curves on surfaces, curvilinear coordinates on a surface, parametric curves on a surface, first fundamental form, first order magnitudes. [8L]

Module IV
Normal to the surface, second Fundamental form, second order magnitudes.
Derivatives of normal to the surface, Weingarten Relations, curvature of normal section, principal and normal curvature, Meunier's theorem, mean curvature, Gauss curvature, lines of curvature, Rodrigue's formula, Euler's theorem. [8L]

Module V
Gauss formulae, Gauss characteristic equation, Mainardi – Codazzi equations. Introduction to geodesics on surfaces, equations of geodesics [8L]

Text Books

1. C.E. Weatherburn, Differential Geometry of Three Dimensions, English Language Book Society and Cambridge University Press, 1964.
2. T. J Willmore, An Introduction to Differential Geometry, Oxford University Press, 1999.

Reference Books

1. Andrew Pressley– Elementary Differential Geometry, Springer-Verlag, 2001, London (Indian Reprint 2004).
2. Manfredo P. Do Carmo– Differential Geometry of Curves and Surfaces, Prentice-Hall, Inc., Englewood, Cliffs, New Jersey, 1976.
3. Barrett O'Neill– Elementary Differential Geometry, 2nd Ed., Academic Press Inc., 2006.
4. William C. Graustein, Differential Geometry, Dover Publications, Inc., New York, 1966.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓		
Quiz (s)	✓	✓	✓		
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 430
Course title: Discrete Mathematical Structure
Pre-requisite(s):
Co- requisite(s):
Credits: 4 L:3 T:0 P:0
Class schedule per week: 03
Class: MSc/MCA
Semester / Level:I/4
Branch: Mathematics/ MCA
Name of Teacher:

Course Objectives : This course enables the students:

A.	To study the methods of reasoning, which includes algebra of propositions, such as compound propositions, truth tables, and tautologies.
B.	To study the recurrence relations, supported by recursive sequences, a tool for the analysis of computer programs. In addition, the generating function, a useful mode for representing sequences efficiently by coding the terms of a sequence as coefficients of powers of a variable in a power series, and its applications in solving recurrence relations will be incorporated here.
C.	To study the discrete structures which are built using sets and their operations; Matrix representation of relations, Digraphs, Classification of Functions and their representation, Discrete Numeric Functions, Growth of Functions.
D.	To study algebraic structures in respect to computer science, because of its variability in applications to computing techniques, in particular programming languages.
E	To study basic graph terminologies and important concepts in graph theory such as types of graphs, storage representation and operations. Also to study here special types of graphs like Eulerian and Hamiltonian.

Course Outcomes : After the completion of this course, students will be able to:

1.	be conversant with the rules of logic to understand and reason with statements
2.	understand about recursion and its use to sequences and also about generating functions and their applications in solving recurrence relations.
3.	handle many of the discrete structures emerged which are indeed useful in Computer Science with the help of set theory approach.
4.	familiar with group theory and its utility. It has variability in applications to computing techniques, such as group codes, coding binary information, decoding , and error correction.
5.	be conversant with important concepts in graph theory such as types of graphs, storage representation and operations. Also to study here special types of graphs like Eulerian and Hamiltonian

Syllabus

MA 430 **Discrete Mathematical Structure** **3-0-0-3**

Module I

Mathematical logic and Mathematical Reasoning, Compound Statements, Propositional Equivalences, Predicates and Quantifiers,Methods of Proof, Mathematical Induction, Well-ordering principle, Recursive Definition and Algorithms. (8L)

Module II

Relations, Properties/Classification of Relations, Closure operations on Relations, Matrix representation of Relations, Digraphs, Partial ordered set, Linearly Ordered Set ,Hasse Diagram, Isomorphism, Isomorphic Ordered Sets, Supremum, Infimum, Well ordered set. (12L)

Module III

Recurrence Relations, Classification of Recurrence Relations and their solutions by Characteristic Root method, Generating function and their various aspects, Utility of Generating function in solving Recurrence Relations (5L)

Module IV

Binary Operations, Groups, Product and Quotients of Groups,Semi group, Products and Quotients of Semi groups, Permutation Group, Composition of Permutation, Inverse Permutation, Cyclic Permutation, Transposition, Even and Odd Permutation, Coding of Binary Information and Error Correction, Decoding and Error Correction. (8L)

Module V

Introduction to Graph, Graph Terminologies and their representation, Connected & Disconnected graphs, Isomorphic Graph, Euler & Hamilton graphs.

Introduction to Trees, Versatility of Trees, Tree traversal, Spanning Trees, Minimum Spanning Tree.

(7L)

Text Books:

1. **Mott , Abraham & Baker** : Discrete Mathematics for computer scientist & mathematicians PHI, 2nd edition 2002.
2. **ROSS & WRIGHT :** Discrete Mathematics PHI 2nd edition , 1988.
3. **Swapan Kumar Chakraborty and BikashKantiSarkar**: Discrete Mathematics, Oxford Univ. Publication, 2010.
4. **Kolman, Rusby, Ross**: Discrete Mathematics Structures, PHI, 5thed, 2005.

Reference Book:

5. **BikashKantiSarkar and Swapan Kumar Chakraborty**:Combinatorics and Graph Theory, PHI, 2016.
6. **Seymour Lipschuz and Mark Lipson**: Discrete Mathematics, Shaum'soutlines, 2003.
7. **C.L.LIU :** Elements of Discrete maths, Mcgraw Hill, 2nd edition, 2001.
8. **Johnsonbaugh, R.,:** Discrete Mathematics, 6th Ed., Maxwell, Macmillan International

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	1	1	2	1	2	2	1	2	2
CO2	3	3	2	1	1	1	2	1	1	2	1	2
CO3	3	2	1	3	3	1	1	1	1	1	2	2
CO4	3	1	2	1	2	2	2	2	1	1	1	2
CO5	2	2	1	2	3	2	2	1	2	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 416
Course title: Statistical Inference
Pre-requisite(s): Basics of Probability and Statistics
Credits: L:3 T:0 P:0 C: 3
Class schedule per week: 3 lectures
Class: **IMSc/MSc**
Semester/level: **VIII/4**
Branch: **Mathematics and Computing** / Mathematics
Name of the Faculty:

Course Objectives : This course will enable the students to understand:

1.	Point Estimation and Interval Estimation
2.	Confidence Interval on Mean, Variance and Proportion
3.	Testing of Hypotheses on the Mean(s) and Variance(s)
4.	Testing for Goodness of Fit
5.	Testing of Independence of Attributes

Course Outcomes : After completion of the course, the students will be able to:

CO1	differentiate between Point Estimate and Interval Estimate and gain an understanding of various methods of Point Estimation.
CO2	describe the various properties of Estimators along with their importance in Estimation Theory.
CO3	gain an understanding of Confidence Interval, Confidence Limits and various concepts related to the Testing of Hypothesis.
CO4	Describe the various steps involved in Testing of Hypothesis problem.
CO5	Demonstrate the use of Chi-square distribution to conduct Tests of (i) Goodness of Fit, and (ii) Independence of Attributes.

Syllabus

MA416 **Statistical Inference** **3-0-0-3**

Module I

Theory of Estimation: Introduction, Point Estimation and Interval Estimation, Methods of Estimation: Method of Maximum Likelihood, Method of Moments; Properties of Estimators: Unbiasedness, Consistency, Efficiency, Sufficiency; Minimum Variance Unbiased Estimator (MVUE), Cramer-Rao Inequality, Minimum Variance Bound (MVB) Estimator, Bayes Estimators. [8L]

Module II

Confidence Interval (CI) Estimation: Introduction, CI on Mean and Variance of a Normal Distribution, CI on a Proportion, CI on the difference between Means for Paired Observations, CI on the ratio of Variances of Two Normal Distributions, CI on the difference between Two Proportions. [8L]

Module III

Tests of Hypotheses: Introduction, Statistical Hypotheses, Type-I and Type-II Errors, One-Sided and Two-Sided Hypotheses, Tests of Hypotheses on the Mean of a Normal Distribution; Variance Known as well as Unknown Cases, Tests of Hypotheses on the Variance of a Normal Distribution, Tests of Hypotheses on a Proportion. [8L]

Module IV

Tests of Hypotheses on the Means of Two Normal Distributions; Variances Known as well as Unknown Cases, The Paired t-Test, Tests for Equality of two Variances, Tests of Hypotheses on two Proportions. [8L]

Module V

Testing for Goodness of Fit, Contingency Table Tests, Neyman-Pearson Theory of Testing of Hypotheses, Uniformly Most Powerful Tests, Likelihood Ratio Tests, Unbiased Tests. [8L]

Text Books:

1. B.K. Kale: A First Course on Parametric Inference, Narosa Publishing House, 1999.
2. E.L. Lehmann: Theory of Point Estimation, John Wiley and Sons, 1998.
3. S.C. Gupta and V.K. Kapoor: Fundamentals of Mathematical Statistics, Sultan Chand and Sons, 2007.

Reference Books:

1. A.M. Goon, M.K. Gupta, B. Dasgupta: Fundamental of Statistics, Vol. I, II, World Press, 2001.
2. V.K. Rohatgi and A.K. Ehsanes Saleh: An Introduction to Probability and Statistics, John Wiley and Sons, Inc. 2003.
3. G. Casella and R.L. Berger: Statistical Inference, Cengage Learning, 3rd Edition, 2008.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

<u>Course Outcome (CO) Attainment Assessment tools & Evaluation procedure</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of Course Outcomes onto Program Outcomes</u>

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 417

Course title: Numerical Solutions of Boundary Value Problems

Pre-requisite(s): Some background in numerical analysis, Ordinary and partial differential equations

Co- requisite(s): ---

Credits: L: 3 T: 0 P:0 C:3

Class schedule per week: 03 Lectures

Class: IMSc/ MSc

Semester / Level: VIII/4

Branch: Mathematics and Computing / Mathematics

Name of Teacher:

Course Objectives: This course enables the students to understand

1.	various forms of difference operators and approaches of finite difference schemes that can be used to approximate the partial differential equation by a suitable grid function defined by a finite number of grid/ mesh points that lie in the underlying domain and its boundary.
2.	recognize three basic types of partial differential equations viz., Hyperbolic, parabolic and elliptic and understand the best suited techniques to be applied to find the solutions to those equations.
3.	analyses numerical issues such as the stability, condition of convergence and the compatibility of the methods that have been introduced to find the numerical solutions of partial differential equation (s) of specific type.
4.	Visualize connection between mathematical expressions and physical meaning of the problem.

Course Outcomes: After the completion of this course, students will be able to

CO1	classify the partial differential equations and approximate the problems using appropriate finite difference scheme
CO2	obtain simple numerical approximations to the solutions to certain boundary value problems
CO3	analyse the consistency, stability and convergence properties of such numerical methods.
CO4	solve eigenvalues problem and physical problems in engineering
CO5	demonstrate the strength of mathematics in modelling and simulating real world problems of science and engineering

Syllabus

MA417 Numerical Solutions of Boundary Value Problems 3-0-0-3

Module I

Finite Differences: Review of finite difference operators and finite difference methods. [8L]

Module II

Hyperbolic PDE: Solution of one and two-dimensional wave equation (hyperbolic equations) using finite difference method, and their limitations and error analysis. [8L]

Module III

Parabolic PDE: Concept of compatibility, convergence and stability, stability analysis by matrix method and Von Neumann method, Lax's equivalence theorem, explicit, full implicit, Crank-Nicholson, du-Fort and Frankel scheme, finite difference methods to solve two-dimensional equations with error analysis. [8L]

Module IV

Elliptic PDE: Five-point formulae for Laplacian, replacement for Dirichlet and Neumann's boundary conditions, curved boundaries, solution on a rectangular domain, block tri-diagonal form and its solution using method of Hockney, condition of convergence. [8L]

Module V

Weighted Residual Methods: Collocation, least squares, Galerkins, Rayleigh-Ritz methods and their compatibility. [8L]

Text Books:

1. L. Lapidus and G.F. Pinder: Numerical Solution of Partial Differential Equations in Science and Engineering, John Wiley, 1982.
2. G.D. Smith: Numerical Solutions to Partial Differential Equations, Oxford University Press, 1986.
3. M.K. Jain, S.R.K. Iyenger and R.K. Jain: Computational Methods for Partial Differential equations, Wiley Eastern, 1994.

Reference Books:

1. C. Johnson: Numerical Solution of Partial Differential Equations by the Finite Element Method, Dover Publications, 2009.
2. H.P. Langtangen: Computational Partial Differential Equations, Springer Verlag, 1999.
3. C.F. Gerald, and P.O. Wheatly: Applied Numerical Analysis, Addison-Wesley Publishing, 2002

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA418
Course title: Mechanics
Pre-requisite(s): Nil
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc/MSc
Semester / Level: VIII/4
Branch: Mathematics and Computing/ Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand:

1.	Motion in different curves under central forces.
2.	The general equation of motion, Compound pendulum, D'Alembert's Principle.
3.	The variational methods, Lagrange and Hamilton's equations of motion, Small oscillations.
4.	Hamilton's principle, Fermat's principle, Principle of least action, Jacobi theory.

Course Outcomes : After the completion of this course, students will be able to:

CO1	solve the problem of central forces and mechanical systems.
CO2	analyze the motion and shape of orbits in planetary motion.
CO3	determine the solution of isoperimetric and Brachistochrone's problems.
CO4	analyze the motion in n-dimensional space.
CO5	demonstrate the strength of mathematics in modelling and simulating real world problems of science and engineering

Syllabus

MA418 Mechanics 3-0-0-3

Module I

Motion of a particle in two dimensions. Velocities and accelerations in cartesian, polar, and intrinsic coordinates. Tangential and normal accelerations. Motion of a particle on a smooth or rough curve. [8L]

Module II

Equation of motion referred to a set of rotating axes, Motion of a projectile in resisting medium. Motion of a particle in a plane under different laws of resistance. [8L]

Module III

Central forces, Stability of nearly circular orbits. Motion under the inverse square law, Kepler's laws, Time of describing an arc and area of any orbit, slightly disturbed orbits. D'Alembert's principle, The general equations of motion, Motion about a fixed axis, Compound pendulum. [8L]

Module IV

Functional, Euler's equations, Isoperimetric problems (Brachistochrone's problem), Functional involving higher order derivatives. Hamilton's principle, Derivation of Lagrange's equations, Generalized coordinates, Holonomic dynamical systems: derivation of Lagrange's equations of motion; Lagrange's function and equation in terms of L. Hamilton's function H and derivatives of Hamilton's equation of motion in terms of Hamiltonian variables. [8L]

Module V

Principle of least action, Fermat's principle, Small oscillations, Lagrange and Poisson Brackets, Contact transformation, Elements of Hamilton Jacobi theory. [8L]

Text Books:

1. Ray M., A text book on Dynamics, S Chand & Company LTD, New Delhi (1982).
2. Gregory R.D., Classical Mechanics, First South Asian Edition, Cambridge Univ. Press (2008).
3. Ramsey A.S., Dynamics Part II, Cambridge Uni Press (1961).

Reference Books:

1. Synge J.L. and Griffith B. A., Principles of Mechanics, McGraw-Hill (1970).
2. Goldstein H., Classical Mechanics, Addison-Wesley Publishing Company (1970)
3. Loney S.L., An Elementary Treatise on the Dynamics of Particle and of Rigid Bodies, Cambridge Uni Press (1913).

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA419
Course title: Mathematical Ecology
Pre-requisite(s): Differential Equations
Co- requisite(s): Basics of Ecology and Environment
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc / MSc
Semester / Level: VIII/4
Branch: Mathematics and Computing/ Mathematics
Name of Teacher:

Course Objectives : This course enables the students

1.	to understand linear and nonlinear system of differential equations and qualitative behaviour of their solutions
2.	to study different types of growths associated with population dynamics
3.	to learn basics required to develop single species, interacting, cooperative and age – structured populations
4.	to analyze the population model systems in the presence of exploitation and harvesting
5.	to compare the stability behaviour of different population ecosystems

Course Outcomes : After the completion of this course, students will be able to

CO1	acquire the skills required to formulate the interactive dynamics that exists between different populations of ecosystems through mathematical models
CO2	assess and articulate the modelling techniques appropriate for a given ecological system
CO3	make predictions of the behaviour of a given ecological system based on analysis of its mathematical model
CO4	do comparative analysis about the stability behaviour between different population ecosystems
CO5	demonstrate the strength of mathematics in simulating real world problems of ecology and environment

Syllabus

MA419 **Mathematical Ecology** **3-0-0-3**

Module I

Autonomous linear and nonlinear systems of differential equations: Equilibrium Solutions, Eigenvalues, Stability analysis, Lyapunov's functions, Phase Plane analysis, Routh – Hurwitz criterion, **[8L]**

Module II

Single Species Models: Exponential, logistic and Gompertz growths, Bifurcations, Harvest models, Bifurcations and Break points, Constant Rate Harvesting, Fox Surplus Yield Model, Allee Effect. **[8L]**

Module III

Interacting Population Models: Lotka Volterra predator-prey models, plane analysis, General predator prey models and their equilibrium solutions, existence of cycles, Bendixson- Dulac's negative criterion, Hopf bifurcation theorem, Bifurcation diagrams, Functional responses, Periodic orbits, Poincare – Bendixson theorem, Freedman and Wolkowicz model. **[8L]**

Module IV

Competition Models: Lotka – Volterra Competition model, Competition Models with Unlimited growth, exploitation competition models, Mutualism models with various types of mutualisms. **[8L]**

Module V

Exploited Population Models: Harvest models with optimal control theory, open access fishery, sole owner fishery, Pontryagin's maximum principle

Structured Population Models: Formulation of spatially and age structured models. **[8L]**

Text Books:

1. Mark Kot, Elements of Mathematical Ecology, Cambridge University Press, 2001.
2. Lawrence Perko, Differential Equations and Dynamical Systems, Springer, 2008.

Reference Books:

1. Nisbet and Gurney, Modelling Fluctuating Populations, John Wiley & Sons, 1982.
2. John Pastor, Mathematical Ecology of Populations and Ecosystems, Wiley – Blackwell Publishers, 2008.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

<u>Course Outcome (CO) Attainment Assessment tools & Evaluation procedure</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of Course Outcomes onto Program Outcomes</u>

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 426
Course title: Operator Theory
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: M.Sc.
Semester / Level: II /4
Branch: Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	Concept of different kinds of bounded linear operators on Hilbert spaces such as, self-adjoint operator, unitary operator, normal operator etc.
2.	Spectrum and different kinds of subdivisions of spectrum of various operators
3.	Idea of spectral representation of compact self-adjoint operators and bounded self-adjoint operators.
4.	Concept of unbounded linear operators in Hilbert spaces

Course Outcomes: After the completion of this course, students will be able to

CO1	Relate the behaviour of different kinds of operators acting on finite dimensional and infinite dimensional spaces
CO2	Understand the difference between the eigenvalue of an operator and spectrum of an operator
CO3	Apply the theory of unbounded operator to differential equations and Difference equations
CO4	Apply the concept of unbounded linear operators in Hilbert spaces
CO5	Apply the theory to study the qualitative behaviour of solutions of different mathematical models in Biological and Ecological system and engineering problems.

Syllabus

MA426 **Operator Theory** **3-0-0-3**

Module I

Review of functional analysis: Normed spaces, Banach spaces, Inner product spaces, Hilbert spaces, Linear transformations, Hanh- Banach theorem, Baire-Category Theorem, Open mapping Theorem, Closed Graph Theorem, Uniform boundedness Theorem. Uniform, strong and weak convergences. [8L]

Module II

Spectral theory of bounded operators on normed spaces, spectrum and resolvant set and their properties, spectral radius, spectral mapping theorem. Subdivisions of spectrum in complex plane: point spectrum, continuous spectrum, residual spectrum, approximate point spectrum etc. Integration of operator valued function, spectral projection.

Compact linear operator on normed spaces, the ideal of compact operators, spectral properties of compact linear operators. Fredholm alternative. [8L]

Module III

Bounded operators on Hilbert spaces; adjoint operators; normal, unitary and self adjoint operators;positive operators and their square root; projection operators, Numerical range, numerical radius. Hilbert-Schmidt operators. Spectral results of normal and self-adjoint operators. [8L]

Module IV

Spectral representations of compact self-adjoint operators, singular value representation of compact operators. Spectral family of a bounded self-adjont operator, Spectral representation of a bounded self-adjont operator, Spectral measure. [8L]

Module V

Unbounded linear operators in Hilbert space: examples, Hilbert-adjoint operators of unbounded linear operators, symmetric and self-adjoint operators, closed linear operators, spectral properties of unbounded self-adjoint linear operators, Multiplication operators and differential operators. [8L]

Text Books:

1. Erwin Kreyszig, Introductory functional analysis with applications, John Wiley and Sons, New York, 1978.
2. M.T. Nair, Functional Analysis: A first course,PHI learning pvt. Ltd. 2010.

Reference Books

1. J. B. Conway, A course in Functional Analysis, Springer Verlag, New York, 1985.
2. P. R. Halmos, A Hilbert space problem book, Van Nostrand, Princeton, New Jersey, 1967.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 427
Course title: MULTIPLE CRITERIA DECISION MAKING
Pre-requisite(s): Optimization including Linear Programming Problem and Non Linear Programming ,concavity,convexity
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 Lectures
Class: IMSc/ MSc
Semester: VIII/4
Branch: Mathematics and Computing/ Mathematics
Course Co-ordinator:

Course Description:

1	Introduction to binary relations and preference , Optimality condition. Pareto optimal or efficient solutions.
2	Introduction, Satisfying solution. Goal settings, Preference ordering and optimality in satisfying solution. Mathematical program and interactive methods. Compromise solutions and interactive methods.
3	About a value function.
4	Learning to Construct general value functions.
5	Domination structures and non-dominated solutions

Course Outcomes: After the completion of the course, the students will be able to:

CO1	learn about what is Pareto optimal or efficient solutions.
CO2	learn about Goal setting and compromise solution.
CO3	learn the Concept of Value Function.
CO4	learn the basic techniques for constructing value functions.
CO5	learn about the Domination structures and non-dominated solutions.

Syllabus

MA 427 **MULTIPLE CRITERIA DECISION MAKING** **3-0-0-3**

Module-I:

Introduction

The needs and basic elements. Binary Relations: Preference as a Binary Relation, Characteristics of Preferences, Optimality condition. Pareto optimal or efficient solutions: Introduction, General Properties of Pareto Optimal Solutions, Conditions for Pareto Optimality in the outcome space, Conditions for Pareto Optimality in the Decision Space. [8L]

Module -II:

Goal setting and compromise solution

Introduction, Satisfying solution. Goal settings, Preference ordering and optimality in satisfying solution. Mathematical program and interactive methods. Compromise solutions. Basic concepts. General properties of compromise solutions. Properties related to p. Computing compromise solutions, interactive methods. [8L]

Module -III:

Value Function.

Revealed preference from a value function. Condition for value functions to exist. Additive and Monotonic value functions and preference separability. Conditions for Additive and monotonic value functions. Structure of preference separability and value functions. [8L]

Module -IV :

Some basic techniques for constructing value functions.

Constructing general value functions. Constructing indifference curves (surfaces).Constructing the tangent planes and gradients of value functions. Constructing the value function. Constructing the additive value functions. A first method for constructing the additive value function. A second method for constructing the additive value function. Approximation method. Approximation method: A general concept. Approximation for additive value functions. Eigen weight vectors for additive value functions. Least distance approximations. [8L]

Module -V:

Domination structures and non-dominated solutions.

Introduction, Domination structures. Constant dominated cone structures. C. A characterization of n-points and their polars. General properties of N-points . Cone convexity and N-points. N points in decision space. Existence properness and duality questions. Local and global N-points in domination structures. Interactive approximation for N-points with information from domination structures.

[8L]

Text books:

1. Po-Lung Yu, Multiple-Criteria Decision Making: concepts, Techniques and Extensions, plenum Press, 1st edition,1985.

2. Evangelos Triantaphyllou ,Multi-Criteria Decision Making Methods: A comparative study, Kluwer Academic Publishers,2000.

Reference:

1. Enrique Ballestero and Carlos Romero, Multiple Criteria Decision Making and its Applications to economic problems, Kluwer Academic Publishers, 1998.

2. Milan Zeleny , Multiple Criteria Decision Making, McGraw-Hill, 1982

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Seminar before a committee	10
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	√	√	√	√	√
End Semester Examination	√	√	√	√	√
Quiz (s)	√	√	√	√	√
Assignment	√	√	√	√	√

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO 12
CO1	3	3	3	3	2	2	2	3	2	3	2	2
CO2	3	3	3	2	2	2	2	2	3	3	2	2
CO3	3	3	3	2	2	2	2	2	3	3	2	2
CO4	2	2	3	3	2	2	2	2	3	3	2	2
CO5	2	2	3	3	2	2	2	2	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 503
Course title: Statistical Computing
Pre-requisite(s):Basics of statistics, probability and algorithms
Co- requisite(s): ---NIL
Credits: 3 L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc / MSc
Semester / Level: IX/ 5
Branch: Mathematics and Computing/ Mathematics
Name of Teacher:

Course Objectives: This course enables the students to get the detailed idea about

1.	Concept of randomness; its types with applications
2.	Pseudo random generator and statistical tests of randomness
3.	Generating random variables from different probability distributions
4.	Fitting statistical models and verifying their goodness of fit
5.	Sampling algorithms and outlier analysis

Course Outcomes: After completion of the course, the learners will be able to

CO1.	Classify randomness and explore the real life applications
CO2.	Develop a new random number generator
CO3.	Simulate variates from different probability distributions
CO4.	Learn to fit various statistical models like time series models and regression models to real life numerical data
CO5.	Select an appropriate sampling algorithm for a real life population and also detect influential observations (outliers) in data and analyses them

Syllabus

MA503 **Statistical Computing** **-0-0-3**

Module I

Understanding randomness, concepts of genuine and false randomness with applications, concept of Kolmogorov's complexity and its applications. [8L]

Module II

Pseudo Random Number Generators (PRNG) including Linear Congruential Generators, Feedback Shift register method, Statistical tests of randomness with applications. [8L]

Module III

Generating random variables from different probability distributions both discrete and continuous, inverse cdf technique, acceptance sampling method. [8L]

Module IV

Modeling in Statistics: regression models, time series models, probability models, goodness of fit tests, graphical statistics. [8L]

Module V

Sampling algorithms, Markov Chain Monte Carlo. Metropolis-Hastings algorithm, Gibbs Sampling algorithm with applications, Outlier Analysis. [8L]

Text Books:

1. William J. Kennedy and James, E. Gentle "Statistical Computing", Marcel Dekker Inc,
2. D. Kundu and A. Basu, Statistical Computing: Existing Methods and Recent Development, Alpha Science International Ltd,

Reference Books:

1. James E. Gentle, Computational Statistics, Springer, 2009
2. S. Chakraborty et. al. A Treatise on Statistical Computing and its Allied Areas, Notion Press

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

<u>Course Outcome (CO) Attainment Assessment tools & Evaluation procedure</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of Course Outcomes onto Program Outcomes</u>

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA504
Course title: Finite Element Methods
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc / MSc
Semester / Level: IX/ 5
Branch: Mathematics and Computing / Mathematics
Name of Teacher:

Course Objectives : This course enables the students to understand

1.	The Methods of weighted residuals, collocations, least squares method.
2.	Variational Methods.
3.	Linear, quadratic and higher order elements.
4.	Interpolation functions, numerical integration, and modelling considerations.

Course Outcomes : After the completion of this course, students will be able to

CO1	determine the solution of engineering problems.
CO2	choose the appropriate methods to solve the physical problems.
CO3	solve the problems of differential equations using FEM.
CO4	determine the solution of initial and boundary value problems.
CO5	demonstrate the strength of mathematics in modelling and simulating real world problems

Syllabus

MA504 **<u>Finite Element Methods</u>** **3-0-0-3**

Module I

Introduction to finite element methods, comparison with finite difference, methods Initial and Eigen value problems, Integral Relations, Functional, Base Functions, The Variational symbol, Formulation of Boundary value problems. Methods of weighted residuals, collocations, least squares method.

[8L]

Module II

Variational Methods of approximation-the Rayleigh-Ritz Method, the method of Weighted Residuals (Gelarkin's Method). Applications to solving simple problems of ordinary differential equations.

[8L]

Module III

Linear, quadratic and higher order elements in one dimensional and assembly, solution of assembled system. [8L]

Module IV

Simplex elements in two and three dimensions, quadratic triangular elements, rectangular elements, serendipity elements and isoperimetric elements and their assembly. Discretization with curved boundaries. [8L]

Module V

Interpolation functions, numerical integration, and modelling considerations. Solution of two dimensional partial differential equations under different Geometric Conditions. [8L]

Text book:

1. Reddy J.N., Introduction to the Finite Element Methods, Tata McGraw-Hill (2003)

Reference Books:

1. Bathe K.J., Finite Element Procedures, Prentice-Hall (2001).
2. Cook R.D., Malkus D.S. and Plesha M.E., Concepts and Applications of Finite Element analysis, John Wiley (2002).
3. Thomas J.R. Hughes, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis (2000).
4. George R. Buchanan, Finite Element Analysis (1994).

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

<u>Course Outcome (CO) Attainment Assessment tools & Evaluation procedure</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of Course Outcomes onto Program Outcomes</u>

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA505
Course title: Calculus of Variations and Optimal Control
Pre-requisite(s): Some background on basic optimization, differential equations, mechanics
Co- requisite(s): ---
Credits: L: 3 T:0 P:0 C:3
Class schedule per week: 3 Lectures
Class: IMSc. / MSc
Semester / Level: IX / 5
Branch: Mathematics and Computing / Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand

11.	the theory of optimizing a functional, typically integral starting with the basic problem of brachistochrone in the calculus of variations.
2.	Knowledge to solve a class of optimization problem in which the function(s) to be optimized under definite integral are restricted with constraint(s)
3.	Learn to establish the necessary conditions for local minimizers using Legendre, Jacobi's and Weierstrass's conditions. solve problems with transversality condition
4.	Solve optimal control problems

Course Outcomes: After the completion of this course, students will be able to

CO1	understand the calculus of variation and optimal control and their related theories.
CO2	handle a class of optimization problem in which the function(s) to be optimized under definite integral are restricted with constraint(s)
CO3	solve optimal control problem using dynamic programming
CO4	apply calculus of variation and optimal control in the areas of optimization
CO5	apply the knowledge of calculus of variation and optimal control to solve a wide range of real world problems of science and engineering

Syllabus

MA505 **Calculus of Variations and Optimal Control** **3-0-0-3**

Module I
Introduction to calculus of variation, the brachistochrone problem, Fundamental Lemma, Necessary condition for an extremum, Euler-Lagrange equation for the function of single and several variables, Variational problems in parametric form and with undetermined end points. [8L]

Module II
Simple isoperimetric problems with single and multiple constraints, application of the problems. [8L]

Module III
Functionals depending on the higher derivatives of the dependent variables, Euler- Poisson equation, Legendre necessary condition, Jacobi's necessary condition**,** Weierstrass's necessary condition, a weak extremum, a strong extremum, transversality condition in general case. [8L]

Module IV
Preliminary Introduction to optimal control problem, necessary condition for optimal control, Linear regulator, Pontryagin minimum principle and state inequality constraints, Hamilton-jacobi-bellman equation. [8L]

Module V
Solving optimal control problem using dynamic programming, structure and properties of optimal control system, various types of constraints, singular solutions, minimum time problem, Bang –bang Controls. [8L]

Text Books:

1. Mike Mesterton, Gibbons, A primer on the calculus of variations and optimal control theory, American Mathematical Society, 2009
2. A. S. Gupta, Calculus of Variations with Applications, Hall of India, 1996.
3. D. S. Naidu: Optimal Control Systems, CRC Press, 2002
4. D. E. Kirk: Optimal Control Theory: An Introduction, Prentice Hall, 2004

Reference Books:

1. R Weinstock, Calculus of Variations with Applications to Physics and Engineering, Dover Publications, 1974
2. D Liberson, calculus of variation and optimal control theory: a concise introduction, Princeton University press, 2011
3. M Athans, and P L Falb, Optimal control: An introduction to the theory and its applications, Dover books on engineering, 2006

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 506

Course title: Advanced Difference Equations

Pre-requisite(s): Sequence and Series of numbers and functions.

Co- requisite(s): ---

Credits: L: 3 T: 0 P: 0 C:3

Class schedule per week: 3 Lectures

Class: IMSc/ MSc

Semester / Level: IX / 5

Branch: Mathematics and Computing / Mathematics

Name of Teacher:

Course Objectives : This course enables the students to understand

1.	application of sequences and series of numbers and functions.
2.	stability theory of difference equations
3.	partial difference equations
4.	applications of partial difference equations in problems of engineering.

Course Outcomes: After the completion of this course, students will be able to

CO1	handle different types of systems: Autonomous (time-invariant) systems, Linear periodic systems.
CO2	apply the theory of difference equations in different midel: Markov Chains, Absorbing Markov Chains, A Trade model.
CO3	apply the theory to study the quantitative and qualitative study of solutions of different discrete models in Engineering and Biology and Ecology.
CO4	differenciate between the qualitative and quantitative behaviour of solutions of the difference equations and the corresponding differential equations.
CO5	apply the theory to study the qualitative theory of solutions of difference equations and partial difference equations of higher order.

Syllabus

MA 506 **Advanced Difference Equations** **3-0-0-3**

Module 1

Introduction and Applications of Difference Equations: Introduction, Mathematics: Summing series, Fibonacci numbers, Chebyshev polynomials, Newton method. Perturbation Techniques: expansion of ϵ, slowly varying amplitude and phase. The Logistic equation: Introduction, The two-cycle, higher cycles, Physical systems: Modeling and time scales, Law of cooling, second-order chemical reaction, rate of dissolution, heat equation. Biological Sciences: Single-species Population models, Harvesting, red blood cell production, Ventilation column and bold CO_2 levels, Simple epidemic model, waves of disease.

[8L]

Module II

Systems of Linear Difference equations: Autonomous (time-invariant) systems: The discrete analogue of the Putzer algorithm, Development of the algorithm for A^n, The Basic theory, The Jordan form: diagonalizable matrices, The Jordan form, Block-Diagonal matrices, Linear periodic systems, Applications in Markov Chains, Absorbing Markov Chains, A Trade model, The Heat equation. [8L]

Module III

Stability Theory: Initial value problems for linear systems, Stability of linear systems, Phase plane analysis for linear systems, Fundamental matrices and Floquet Theory, Stability of Nonlinear systems. Applications of Floquet theory in Engineering problems. Lyapunov's Direct or Second method: Applications to models in one species with two age classes, Host-parasitoid systems, A business cycle model, Nicholson-Bailey model and Floor Beetle case study. [8L]

Module IV

The Self-Adjoint Second Order Linear Equations: Introduction, Sturmian Theory, Green's functions, Disconjugacy, The Riccatti equation. The Sturm-Liouville Problem: Introduction, Finite Fourier analysis, Nonhomogeneous problem. Discrete Calculus of Variations: Introduction, Necessary conditions for Disconjugacy, Sufficient conditions for disconjugacy. Boundary Value Problems for Nonlinear Equations: Introduction, The Lipschitz case, Existence of solutions, Boundary value problems for Differential equations. [8L]

Module V

Partial Difference Equations: Discretization of Partial Differential Equations, Solutions of partial difference equations. Numerical Solutions of Partial Difference Equations: Convergence and consistency of solutions of initial-value problems, Initial-Boundary value problems, The Lax theorem, Examples. Computational Interlude-Review of computational results, HW0.0.1, Implicit Scheme, Neumann boundary conditions. Stability: Analysis of stability, Finite Fourier series and stability, Examples, Consistency and stability of some parabolic equations and hyperbolic equations. Dispersion and Dissipation: Introduction, Dispersion and dissipation for difference equations, Artificial Dissipation.

[8L]

Text Books:

1. W. G. Kelley and Allan C. Peterson, Difference Equations: An Introduction with Applications, Academic Press, Second Edition, 2001.
2. Saber Elaydi, An Introduction to Difference Equations, Third Edition, Springer, New York, 2005.
3. J.W.Thomas, Numerical Partial Differential equations, Springer, 1995.
4. R. E. Mickens, Difference Equations: Theory, Applications and Advanced Topics, CRC Press, Third Edition, 2015.

Reference Books:

1. Kenneth S. Miller, An Introduction to the Calculus of Finite Differences and Difference Equations, Dover Publications, New York, 1960.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

<u>Course Outcome (CO) Attainment Assessment tools & Evaluation procedure</u>

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of Course Outcomes onto Program Outcomes</u>

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA507
Course title: Computational Fluid Dynamics
Pre-requisite(s): Partial Differential Equations
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc/ MSc
Semester/level: IX/5
Branch: Mathematics and Computing / Mathematics
Name of the Faculty:

Course Objectives: This course enables the students to understand

1.	the basis of finite difference method to solve the partial differential equation.
2.	the uses of Finite Volume method and limitation of finite difference method.
3.	the analysis, applications and limitations of numerical schemes.
4.	the numerical approach to solve compressible Euler equations.
5	the numerical approach to solve the incompressible Navier-Stokes equations.

Course Outcomes: After the completion of this course, students will be able to

CO 1	learn the background and get an introduction for the use of numerical methods to solve partial differential equations.
CO 2	apply the concepts of finite difference and finite volume methods to solve the fluid mechanics problem and other real word problems
CO 3	analyse the consistency, stability and convergence analysis of numerical schemes.
CO 4	choose appropriate numerical methods to solve the fluid flow problem.
CO 5	understand the limitation of numerical methods and various techniches in actual implementation.

Syllabus

MA507 **Computational Fluid Dynamics** **3-0-0-3**

Module I

Basic equations of fluid dynamics: General form of a conservation law; Equation of mass conservation; Conservation law of momentum; Conservation equation of energy. Incompressible form of the Navier-Stokes equations, 2D incompressible Navier-Stokes equations, Stream function-vorticity formulation, Mathematical and physical classification of PDEs.

[6L]

Module II

Basic Discretization techniques: Finite Difference Method (FDM); The Finite Volume Method (FVM) and conservative discretization. Analysis and Application of Numerical Schemes: Consistency; Stability; Convergence; Fourier or von Neumann stability analysis; Modified equation; Application of FDM to wave, Heat, Laplace and Burgers equations.

[15L]

Module III

Integration methods for systems of ODEs: Linear multistep methods; Predictor-corrector schemes; The Runge Kutta schemes. **[6L]**

Module IV

Numerical solution of the compressible Euler equations: Mathematical formulation of the system of Euler equations; Space centred schemes; upwind schemes for the Euler equations flux vector and flux difference splitting. **[6L]**

Module V

Numerical solution of the incompressible Navier-Stokes equations: Stream function vorticity formulation; Primitive variable formulation. Pressure correction techniques like SIMPLE, SIMPLER and SIMPLEC.

[7L]

Text Books:

1. Richard Pletcher, John Tannehill and Dale Anderson, Computational Fluid Mechanics and Heat Transfer 3e', CRC Press, 2012.
2. H.K. Versteeg and W. Malalasekera, An introduction to computational fluid dynamics: The finite volume method 3e, Pearson Education, 2007.
3. Charles Hirsch, Numerical Computation of Internal and External Flows, Vol.1 (1988) and Vol.2 (1990), John Wiley & Sons.

Reference Books:

1. Pradip Niyogi, S.K. Chakrabarty, M.K. Laha, Introduction to computational fluid dynamics, Pearson Education India, 1985.
2. J. H. Fergiger and M. Peric, Computational Methods for Fluid Dynamics, Springer, 2002.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 508
Course title: Qualitative Theory of Differential equations
Pre-requisite(s): Basics of Ordinary and Partial Differential Equations
Co- requisite(s): ---
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc/ MSc
Semester / Level: IX/5
Branch: Mathematics and Computing/ Mathematics
Name of Teacher:

Course Objectives : This course enables the students to understand

1.	the advanced theory of ordinary and partial differential equations
2.	the concept of Existence and uniqueness of solutions of differential equations.
3.	the concept of stability theory of differential equations.
4.	Green's functions of boundary value problems.

Course Outcomes: After the completion of this course, students will be able to

CO1	handle and analyse the problems related to ordinary and partial differential equations.
CO2	study the qualitative behaviour of solutions of ordinary and partial differential equations
CO3	handle the partial differential equations in theory of Biological, Ecological systems and different engineering problems.
CO4	use of Green's functions in the study of qualitative behaviour of solutions of boundary value problems.
CO5	enhance and develop the ability of using the language of mathematics in analysing the real world problems of sciences and engineering.

Syllabus

MA508 **<u>Qualitative Theory of Differential equations</u>** **3-0-0-3**

Module 1

Systems of Ordinary Differential Equations: Existence, uniqueness and continuity, Gronwall Inequality Linear Systems and Phase Space Analysis: Introduction, Existence and uniqueness of Linear Systems, Linear homogeneous and non homogeneous systems, Linear Systems with Constant coefficients, Jordan Canonical form, Autonomous Systems- Phase space-two dimensional systems. [8L]

Module II

Existence Theory: Existence theory for systems of first order equations, uniqueness and continuation of solutions. Stability of linear and almost linear systems: Introduction, Definition of stability, linear systems, almost linear systems, conditional stability. [8L]

Module III

Lyapunov's Second method: Lyapunov's theorems, Proofs of Lyapunov's theorems, Invarient sets and stability, global asymptotic stability, nonautonomous systems. [8L]

Module IV

Sturm-Liouville Systems, Eigen values and Eigen functions, Singular Sturm-Liouville Systems.
Method of separation of variables: Separation of variables, The vibrating string problem, Existence and uniqueness of solutions of the vibrating string problem, heat equation, heat conduction problem, Existence and uniqueness of solutions of heat conduction problem.
Elliptic Equations: Elliptic equations with Dirichlet, Neumann and Cauchy boundary conditions, Maximum and minimum principles, Dirichlet and Neumann problems for a rectangle, Green's function for Laplace equations. [8L]

Module V

Green's function and Boundary Value Problems: Introduction, Properties of green's function, Method of Green's functions, Dirichlet's Problem for Laplace Operator, Dirichlet's problem for Helmholtz operator, Method of Eigen functions, Higher-Dimensional Problems, Neumann Problem. [8L]

Text Books:

1. F. Brauer and J. A. Nohel, The Qualitative Theory of Ordinary Differential equations, Dover Publications, New York, 1989.
2. Tyn Myint U and Debnath Loknath, Linear partial Differential Equations for Scientists and Engineers, Birkhauser, 4^{th} Edition, 2007.

Reference Books:

1. Ravi P. Agarwal and Donal O'Regan, An Introduction to Ordinary Differential Equations, Universitext, Springer, 2008.
2. Ravi P. Agarwal and Donal O'Regan, Ordinary and Partial Differential equations, With Special Functions, Fourier Series and Boundary Value Problems, Universitext, Springer, 2009.

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3

COURSE INFORMATION SHEET

Course code: MA 523
Course title: Computational Mathematics
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc/MSc
Semester / Level: VII/4
Branch: Mathematics and Computing/Mathematics
Name of Teacher:

Course objectives: This course is intended as an advance course enables the students to get the detailed idea about:

1.	Partial differential equations
2.	boundary value problem
3.	Calculus of Variations
4.	Eigen values and eigen vectors of Matrices
5.	Numerical method: Finite difference method
6.	Introduction to finite element method

Course Outcomes: After completion of the course, the learners will be able to:

CO1.	formulate the continuous physical systems using mathematical notations as partial differential equations since most entities in the real world are dependent of several independent entities and handle real dynamic problems with diversity and complexity which leads to boundary value problem
CO2.	gain an understanding of eigen value problem and gain skills in modelling and solving eigen value problem.
CO3.	handle huge amount of problems in science and engineering physics where one has to minimize the energy associated to the problem under consideration.
CO4.	solve problems involving differential equations, ordinary and partial with regular as well as irregular boundaries.
CO5.	demonstrate a depth of understanding in advanced mathematical topics and enhance and develop the ability of using the language of mathematics in Science and engineering

Syllabus

MA 523 **Computational Mathematics** **3-0-0-3**

Module I

Partial Differential Equations:

Classification of partial differential equations. Its characteristics and reduction to canonical forms. Solution of higher order p.d.e with variable co-efficients by Monge's method. Boundary value Problems. Laplac's equation in different co-ordinate systems. Two-dimensional heat conduction equation. Vibrating membrane. [8L]

Module II

Eigen values and eigen vectors of Matrices:

Basic properties of eigen values and eigen vectors. The power method. The Rayleigh quotient. Inverse iteration. Jacobi's methods, Given and Household's methods. Leverriar – Faddeeva method. Sylvester's expansion theorem and Computation of f(A). [8L]

Module III

Numerical method: Finite difference method for parabolic, elliptic and hyperbolic equations. Explicit and implicit schemes. Convergence and Stability of schemes. [8L]

Module IV

Calculus of Variations:

The Euler equation of Variations, the extrema of integrals under constraints. Sturm-Liouville Problems. Hamilton's principle and Lagrange's equations. [8L]

Module V

Introduction to finite element method.

Concept of functionals. Rayleigh Ritz and Galerkin's Techniques. Finite element method for one dimensional problems. Application to two dimensional problems. [8L]

Test Books:

1. Advanced Engineering Mathematics – E. Kreyszig
2. Linear Partial Differential Equations for Scientists and Engineers, Lokenath Debnath and Tyn Myint U., Fourth Edition, Birkhauser, Boston.
3. I.N.Sneddon, Elements of Partial Differential Equations, **McGraw Hill, NewYork, 2006.**
4. J.N. Reddy , An Introduction to the Finite Element Method ; McGraw Hill Energy and variational Methods in Applied mechanics .

Reference Books:

1. J D Hoffman, Numerical Methods for Engineers and Scientists, **McGraw Hill Inc., NewYork, 2001.**
2. O.C. Zienkiewicz , The Finite Element Method,
3. J N Reddy , Energy and variational Methods in Applied mechanics .

Course delivery methods	
Lecture by use of boards/lcd projectors/ohp projectors	√
Tutorials/assignments	√
Seminars	
Mini projects/projects	√
Laboratory experiments/teaching aids	
Industrial/guest lectures	
Industrial visits/in-plant training	
Self- learning such as use of nptel materials and internets	√
Simulation	

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
End Semester Examination	50
Quiz (s)	10+10+10
Assignment	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Seminar before a committee	✓	✓	✓	✓	✓
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	1	1	1	1	3	2	3	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2
CO5	2	2	3	3	1	1	1	1	3	3	1	2

If satisfying< 34%=1, 34-66% =2, > 66% = 3