BIRLA INSTITUTE OF TECHNOLOGY
MESRA-835215

NEP-BASED CHOICE BASED CREDIT SYSTEM (CBCS) PROGRAMME

Integrated Master of Science in Mathematics and Computing

(Effective from Academic Session: Monsoon 2023)

Department of Mathematics

NEP-BASED CBCS Programme for IMSc in Mathematics and Computing
(1st -10th Semester)

Important notes:

- The essential guidelines from UGC dated 07 Dec 2022 have been followed in the preparation of the course structure of this programme.
- The NEP-2020 guidelines for awarding Certificate, Diploma, and Degree

  I Year UG Certificate: Students who opt to exit after completing the first year and have secured a minimum of 40 credits will be awarded a UG certificate provided they complete a 4-credit summer vocational program.

  II Year UG Diploma: Students who opt to exit after completing the second year and have secured a minimum of 80 credits will be awarded the UG diploma provided they have completed a 4-credit summer vocational program.

  III Year UG Degree: Students who opt to exit after 3-years will be awarded a ***B.Sc. Degree,*** provided they have earned a minimum of 120 credits as per Table- I.

  IV Year UG Degree (Honours): A four-year ***B.Sc. (Honours) Degree*** will be awarded upon completion of a minimum of 160 credits as per Table-I.

Table -I: Minimum Credit Requirements to Award UG Degree as per NEP guidelines:

S.N.	**Broad Category of Course**	Minimum Credit Requirement	
		3-year UG	**4-year UG**
1.	Major (Core)	60	80
2.	Minor Stream	24	32
3.	Multidisciplinary (MDC)	09	09
4.	Ability Enhancement Courses (AEC)	08	08
5.	Skill Enhancement Courses (SEC)	09	09
6.	Value Added Courses (VAC)	06-08	06-08
7.	Summer Internship (SI)	02-04	02-04
8.	Research Project / Dissertation	-	12
	Total (up to 4-Year)	**120**	**160**

Note: Honours students not undertaking research will do 3 courses for 12 credits in lieu of a research project / Dissertation.

- Otherwise IMSc in Mathematics and Computing would be offered to them after the successful completion of 10^{th} semester.

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 society.

Department Mission

- Imparting strong fundamental concepts to students in the field of Mathematical Sciences and motivating 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.

Graduate Attributes

1. **Engineering Knowledge**: Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.
2. **Problem Analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/ Development of Solutions**: Design solutions for complex engineering problems and design system components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems** using research-based knowledge and research methods including design of experiments, analysis and interpretation of data and synthesis of information to provide valid conclusions.
5. **Modern Tool Usage**: Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.
6. **The Engineer and Society**: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues, and the consequent responsibilities relevant to professional engineering practice.
7. **Environment and Sustainability**: Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.
9. **Individual and Teamwork**: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.

10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project Management and Finance**: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long Learning**: Recognize the need for and have the preparation and ability to engage in independent and life- long learning in the broadest context of technological change.

Program Educational Objectives (PEOs)

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.

(A) Programme Outcomes (POs)

A graduate of this program is expected to:
1. gain sound knowledge on fundamental principles and concepts of Mathematics and computing 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 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.

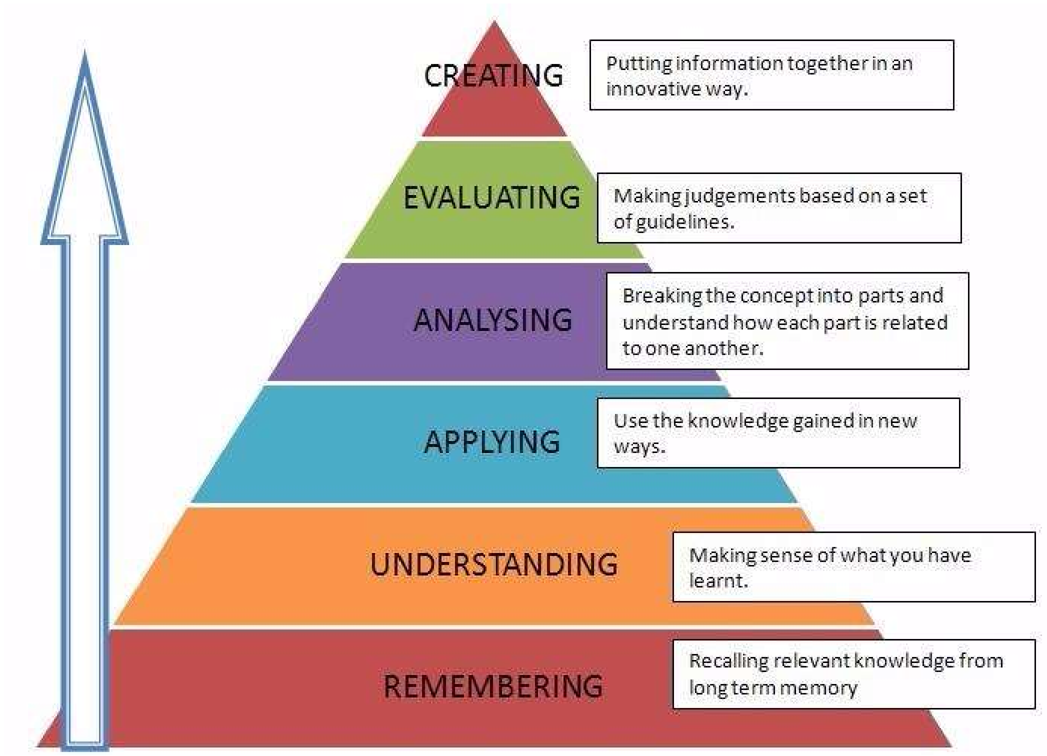
(B) Programme Specific Outcomes (PSOs)

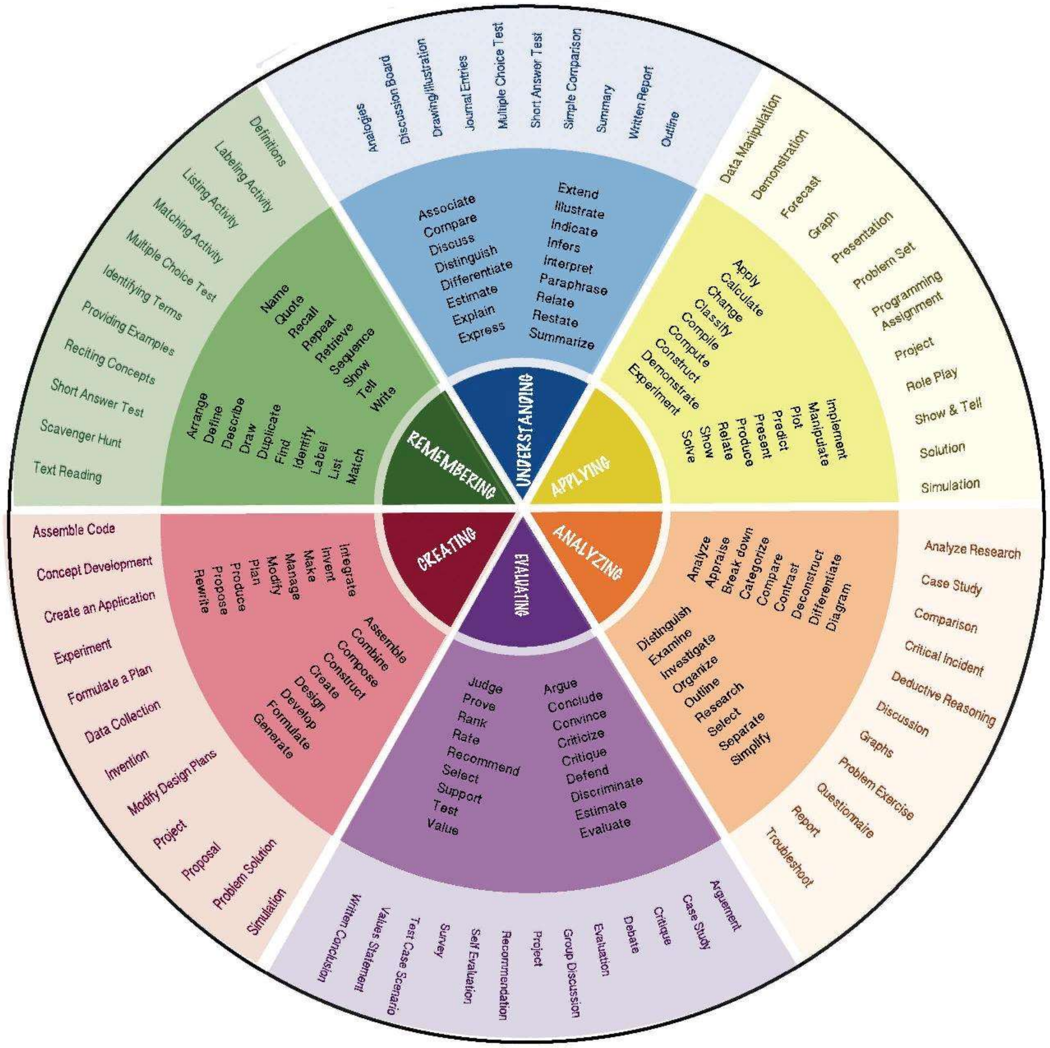
1. Apply in-depth knowledge gained during the Integrated MSc. Mathematics and Computing program in analyzing and interpreting real life problems for providing the optimal and achievable solutions.
2. Demonstrate combined knowledge of mathematics and computing to manage projects efficiently and economically with intellectual integrity and ethics for sustainable development of society.
3. Capable of using his/her knowledge of mathematical sciences in higher studies of an interdisciplinary nature.

BLOOM'S TAXONOMY FOR CURRICULUM DESIGN AND ASSESSMENT:

Preamble

The design of curriculum and assessment is based on Bloom's Taxonomy. A comprehensive guideline for using Bloom's Taxonomy is given below for reference.




REMEMBERING
Name
Quote
Recall
Repeat
Retrieve
Sequence
Show
Tell
Write
Arrange
Define
Describe
Draw
Duplicate
Find
Identify
Label
List
Match
Definitions
Labeling Activity
Listing Activity
Matching Activity
Multiple Choice Test
Identifying Terms
Providing Examples
Reciting Concepts
Short Answer Test
Scavenger Hunt
Text Reading
UNDERSTANDING
Associate
Compare
Discuss
Distinguish
Differentiate
Estimate
Explain
Express
Extend
Illustrate
Indicate
Infers
Interpret
Paraphrase
Relate
Restate
Summarize
Analogies
Discussion Board
Drawing/Illustration
Journal Entries
Multiple Choice Test
Short Answer Test
Simple Comparison
Summary
Written Report
Outline
APPLYING
Apply
Calculate
Change
Classify
Compile
Compute
Construct
Demonstrate
Experiment
Implement
Manipulate
Plot
Predict
Present
Produce
Relate
Show
Solve
Data Manipulation
Demonstration
Forecast
Graph
Presentation
Problem Set
Programming Assignment
Project
Role Play
Show & Tell
Solution
Simulation
ANALYZING
Analyze
Appraise
Break down
Categorize
Compare
Contrast
Deconstruct
Differentiate
Diagram
Distinguish
Examine
Investigate
Organize
Outline
Research
Select
Separate
Simplify
Analyze Research
Case Study
Comparison
Critical Incident
Deductive Reasoning
Discussion
Graphs
Problem Exercise
Questionnaire
Report
Troubleshoot
EVALUATING
Judge
Prove
Rank
Rate
Recommend
Select
Support
Test
Value
Argue
Conclude
Convince
Criticize
Critique
Defend
Discriminate
Estimate
Evaluate
Arguement
Case Study
Critique
Debate
Evaluation
Group Discussion
Project
Recommendation
Self Evaluation
Survey
Test Case Scenario
Values Statement
Written Conclusion
CREATING
Integrate
Invent
Make
Manage
Modify
Plan
Produce
Propose
Rewrite
Assemble
Combine
Compose
Construct
Create
Design
Develop
Formulate
Generate
Assemble Code
Concept Development
Create an Application
Experiment
Formulate a Plan
Data Collection
Invention
Modify Design Plans
Project
Proposal
Problem Solution
Simulation

BIRLA INSTITUTE OF TECHNOLOGY- MESRA, RANCHI							
COURSE STRUCTURE - To be effective from Academic Session MO-2023							
(*For Integrated MSc. in Mathematics and Computing*)							
FIRST YEAR							
Semester	**Category**	**Course Code**	**Subjects**	**Mode of delivery**			**C-Credits**
				L	**T**	**P**	**C**
FIRST	**THEORY**						
	Major	MA101	Calculus-I	3	1	0	4
		MA102	Real Analysis	3	1	0	4
		MA109	Matrix Theory	3	1	0	4
	Minor	CH111	Chemistry I	3	1	0	4
	SESSIONAL						
	Minor	CH112	Chemistry I Lab	0	0	4	2
	AEC	MT132	Communication Skill I	0	0	3	1.5
	VAC (Any one)	MC101	NCC	0	0	2	1
		MC102	NSS				
		MC103	PT & Games				
		MC104	Creative Arts (CA)				
		MC109	Entrepreneurship				
FIRST SEMESTER TOTAL							**20.5**
SECOND	**THEORY**						
	Major	MA105R1	Calculus-II	3	0	0	3
		MA106R1	Ordinary Differential Equations	3	0	0	3
		MA110R1	Complex Analysis	3	0	0	3
	Minor	PH109	Physics I	3	1	0	4
	VAC	CE101	Environmental Science	2	0	0	2
	SEC	CS101	Programming for problem solving	3	1	0	4
	SESSIONAL						
	Minor	PH110R1	Physics I Lab	0	0	4	2
	SEC	CS102	Programming for problem solving Lab	0	0	3	1.5
	VAC (Any one)	MC105	NCC	0	0	2	1
		MC106	NSS				
		MC107	PT & Games				
		MC108	Creative Arts (CA)				
		MC110	Entrepreneurship				
SECOND SEMESTER TOTAL							**23.5**
FIRST YEAR GRAND TOTAL							**44**
Vocational Summer Training for Certificate			Web Designing	1	0	6	4
Minimum requirement for Certificate in Mathematics and Computing (After First Year)							**48**

SECOND YEAR							
Semester	Broad Category	Course Code	Subjects	Mode of delivery			C-Credits
				L	T	P	C
THIRD	THEORY						
		MA202R1	Abstract Algebra	3	0	0	3
		MA201R1	Partial Differential Equations	3	0	0	3
	Minor	PH111	Physics II	3	1	0	4
	Major	CS231	Data Structures	3	1	0	4
	AEC	PE309	Project Management	3	0	0	3
	SESSIONAL						
	Minor	PH112	Physics II Lab	0	0	4	2
	Major	CS232	Data Structures Lab	0	0	3	1.5
	VAC (Any one)	MC201	NCC	0	0	2	1
		MC202	NSS				
		MC203	PT & Games				
		MC204	Creative Arts (CA)				
		MC209	Entrepreneurship				
THIRD SEMESTER TOTAL							21.5
FOURTH	THEORY						
	Major	MA206R1	Linear Algebra	3	0	0	3
		MA210	DMS and Graph Theory	3	1	0	4
	SEC	CS233	OOP and Design Pattern	3	0	0	3
	Minor	CH213	Chemistry II	3	1	0	4
	MDC	OE1	OE1(UG)	3	0	0	3
	SESSIONAL						
	SEC	CS234	OOP and Design Pattern Lab	0	0	3	1.5
	Minor	CH214	Chemistry II Lab	0	0	4	2
	VAC (Any one)	MC205	NCC	0	0	2	1
		MC206	NSS				
		MC207	PT & Games				
		MC208	Creative Arts (CA)				
		MC210	Entrepreneurship				
FOURTH SEMESTER TOTAL							21.5
SECOND YEAR GRAND TOTAL							87
Vocational Summer Training for Diploma			3D Printing and Designing (AICTE IDEA Lab)	1	0	6	4
Minimum requirement for Diploma in Mathematics and Computing (After Second Year)							91

THIRD YEAR							
Semester	**Broad Category**	**Course Code**	**Subjects**	**Mode of delivery**			**C-Credits**
				L	**T**	**P**	**C**
FIFTH	**THEORY**						
		MA311R1	Numerical Techniques	3	0	0	3
		MA301R1	Probability and Statistics	3	0	0	3
		CS 241	Design and Analysis of Algorithms	3	0	0	3
	Major PE-1 (Any one)	MA303R1	Fuzzy Logic	3	0	0	3
		MA208R1	Integral Transforms and its Applications				
		MA315R1	Financial Mathematics				
		MA209R1	Integral Equations and Green's Function				
	MDC	OE	OE2(UG)/OE4(UG)	3	0	0	3
	SESSIONAL						
	Major	MA312R1	Numerical Techniques Lab	0	0	2	1
		CS 242	Design and Analysis of Algorithms Lab	0	0	2	1
	AEC	MT133	Communication Skill II	0	0	3	1.5
FIFTH SEMESTER TOTAL							**18.5**
SIXTH	**THEORY**						
	Major	MA309R1	Optimization Techniques	3	0	0	3
		CS 301	Database Management System	3	0	0	3
		CS 303	Operating Systems	3	0	0	3
	Major PE-2 (Any one)	MA307	Computational Linear Algebra	3	0	0	3
		MA308	Difference Equations				
		CS321	Soft Computing				
		MA316R1	Statistical Quality Control and Reliability				
		CS324	System Programming				
		CS325	Database Modelling				
	MDC	OE	OE3(UG)	3	0	0	3
	AEC	MT403	Organisational Behaviour	2	0	0	2
	SESSIONAL						
	Major	MA310R1	Optimization Techniques Lab	0	0	2	1
		CS 302	Database Management System Lab.	0	0	3	1.5
	SI		Summer Internship (Industry/Institute)	0	0	4	2
SIXTH SEMESTER TOTAL							**21.5**
THIRD YEAR GRAND TOTAL							**127**
Minimum requirement for Degree award of B.Sc. in Mathematics and Computing							**127**

FOURTH YEAR							
Semester	Broad Category	Course Code	Subjects	Mode of delivery			C-Credits
				L	T	P	C
SEVENTH	THEORY						
	Major	MA401R1	Measure Theory and Integration	3	0	0	3
		MA402R1	Advanced Complex Analysis	3	0	0	3
		CS 310	Formal Languages & Automata Theory	3	0	0	3
		CA505	Software Engineering	3	1	0	4
	Major PE-3 (Any one)	MA404	Mathematical Epidemiology	3	0	0	3
		MA405	Mathematical Modelling				
		MA406	Fuzzy Mathematical Programming				
		CS391	Introduction to Distributed System				
		MA408	Theory of Elasticity				
		CA532	Data Mining and Warehousing				
	Minor	BT417	Bioinformatics	3	0	0	3
	SESSIONAL						
	Major	CA506	Software Engineering Lab	0	0	3	1.5
SEVENTH SEMESTER TOTAL							**20.5**
EIGHTH	THEORY						
	Major	MA431	Applied Functional Analysis	3	1	0	4
		MA502	Number Theory	3	1	0	4
		CA413	Data Communication and Computer Networks	3	0	0	3
	Major PE-4 (Any one)	MA413	Stochastic Processes and Simulation	3	0	0	3
		MA416	Statistical Inference				
		MA418	Mechanics				
		MA419	Mathematical Ecology				
		MA427	Multiple Criteria Decision Making				
		MA524	Advance Mathematical Technique				
	Minor	GI509R1	Digital Satellite Image Processing	3	0	0	3
	SESSIONAL						
	Minor	GI509R1	Digital Satellite Image Processing Lab	0	0	4	2
	Major	CA414	Data Communication and Computer Networks Lab	0	0	3	1.5
EIGHTH SEMESTER TOTAL							**20.5**
FOURTH YEAR GRAND TOTAL							**168**
Minimum requirement for Degree award of B.Sc. Honours in Mathematics and Computing							**168**

FIFTH YEAR							
Semester	Broad Category	Course Code	Subjects	Mode of delivery			C-Credits
				L	T	P	C
NINTH	THEORY						
	Major	MA414R1	Advanced Operation Research	3	0	0	3
		CA511	Basics of Machine Learning	3	0	0	3
		CA601	Computer Graphics	3	0	0	3
	Major PE-5 (Any two)	MA503	Statistical Computing	3	0	0	6
		MA505	Calculus of Variations and Optimal Control				
		MA506	Advanced Difference Equations				
		MA507	Computational Fluid Dynamics				
		MA510	Advance Differential Equations				
		MA523	Computational Mathematics				
		CA529	Network Security & Cryptography				
		MA412R1	Topology				
		MA318	Artificial Neural Network				
		CA635	Natural Language Processing				
	VAC	MT204	Constitution of India	2	0	0	0
	SESSIONAL						
	Major	CA512	Basics of Machine Learning	0	0	3	1.5
		CA602	Computer Graphics Lab	0	0	3	1.5
NINTH SEMESTER TOTAL							18
TENTH	Major	MA509	Research Project / Industry Internship	0	0	0	20
TENTH SEMESTER TOTAL							20
FIFTH YEAR GRAND TOTAL							206
Minimum requirement for Degree award of Integrated M. Sc. in Mathematics and Computing							206

DEPARTMENT OF MATHEMATICS							
PROGRAMME ELECTIVE (PE) OFFERED FOR SEMESTER 5-9							
PE	**Prerequisites Subjects**	**Code no.**	**Name of the PE subjects**	**L**	**T**	**P**	**C**
PE-1		MA303R1	Fuzzy Logic	3	0	0	3
	MA105R1	MA208R1	Integral Transforms and its Applications	3	0	0	3
	MA301	MA315R1	Financial Mathematics	3	0	0	3
	MA201R1	MA209R1	Integral Equations and Green's Function	3	0	0	3
PE-2	MA201R1	MA307	Computational Linear Algebra	3	0	0	3
	MA201R1	MA308	Difference Equations	3	0	0	3
	MA205	CS321	Soft Computing	3	0	0	3
	MA301R1	MA316R1	Statistical Quality Control and Reliability	3	0	0	3
		CS324	System Programming	3	0	0	3
	CS301	CS325	Database Modelling	3	0	0	3
PE-3	MA201R1	MA404	Mathematical Epidemiology	3	0	0	3
	MA201R1	MA405	Mathematical Modelling	3	0	0	3
	MA210	MA406	Fuzzy Mathematical Programming	3	0	0	3
	MA201R1	MA408	Theory of Elasticity	3	0	0	3
		CS391	Introduction to Distributed System	3	0	0	3
		CA532	Data Mining and Warehousing	3	0	0	3
PE-4	MA301R1	MA413	Stochastic Processes and Simulation	3	0	0	3
	MA301R1	MA416	Statistical Inference	3	0	0	3
	MA201R1	MA418	Mechanics	3	0	0	3
	MA201R1	MA419	Mathematical Ecology	3	0	0	3
		MA524	Advance Mathematical Technique	3	0	0	3
	MA309R1	MA427	Multiple Criteria Decision Making	3	0	0	3
PE-5	MA301R1	MA503	Statistical Computing	3	0	0	3
	MA201R1	MA505	COV and Optimal Control	3	0	0	3
	, MA201R1	MA506R1	Advanced Difference Equations	3	0	0	3
	MA201R1	MA507	Computational Fluid Dynamics	3	0	0	3
	MA201R1	MA510	Advance Differential Equations	3	0	0	3
	MA201R1	MA523	Computational Mathematics	3	0	0	3
		CA529	Network Security & Cryptography	3	0	0	3
		MA412R1	Topology	3	0	0	3
	MA105R1	MA318	Artificial Neural Network	3	0	0	3
		CA635	Natural Language Processing	3	0	0	3

BIRLA INSTITUTE OF TECHNOLOGY- MESRA, RANCHI				
REVISED COURSE STRUCTURE				
Based on NEP-2020				
Recommended scheme of study				
Details of credits distribution for IMSc in Mathematics and Computing (category wise)				
S.N.	**Broad Category**	Minimum Credit Requirement		
		B.Sc.	B.Sc. (Honours)	IMSc
1	Major Courses (Mathematics & Computer Science)	68	101	119
2	Minor Stream	24	32	32
3	Multidisciplinary Courses (MDC)	9	9	9
4	Ability Enhancement Courses (AEC)	8	8	8
5	Skill Enhancement Courses (SEC)	10	10	10
6	Value Added Courses common for all UG	6	6	6
7	Summer Internship (SI)	2	2	2
7	Research Project / Dissertation	0	0	20
	GRAND TOTAL	127	168	206
Honours students not undertaking research will do 3 courses for 12 credits in lieu of a research project / Dissertation				

COURSE INFORMATION SHEET

Course code: MA101
Course title: Calculus-I
Pre-requisite(s): Basics of differential Calculus and integral Calculus
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 lectures, 1 tutorial
Class: IMSc
Semester/level: I/1
Branch: Mathematics and Computing
Course Objectives: This course enables the students to understand the

1.	behavior of functions studying different approach of derivatives for the function of single variable.
2	nature of the function in cartesian and polar form and its behavior at infinity.
3.	functions of two or more variables, their differentiation, properties and applications as most of entities in the real world are dependent of several independent entities
4.	definite Integral, improper integrals and some special integrals such as Beta functions, Gamma Functions and Error functions.
5	applications of the definite Integral to derive different important quantities as arc length, area, volume, work and moments.

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

CO1	find the nth derivatives of the function, evaluate its indeterminate forms and way to expand a function in series form using Taylor's and Maclaurin's theorems. analytically and graphically understand the nature and forms of function
CO2	study behavior of a function at infinity, knowledge on curvature with its properties in both cartesian and polar form.
CO3.	understand the fundamental concepts of functions with several variables, its derivatives in partial forms with other important related concepts, their applications in maxima - minima problems.
CO4.	apply the principles of integral to solve a variety of practical problems in sciences and engineering.
CO5.	enhance and develop the ability of using the language of mathematics in analyzing the real-world problems of sciences and engineering.

Syllabus

MA101 Calculus-I 3-1-0-4

Module I

Successive Differentiation and Mean Value Theorem: Leibnitz Theorem, Generalized Mean Value Theorem, Taylor's and Maclaurin's Expansion of Functions of Single Variable**.** Increasing and decreasing functions. Concavity, Convexity and Inflection point of a function. Extrema of functions. [6L]

Module II

Analysis of functions: Behavior of a function at infinity: Asymptotes. Orthogonal Intersection of Curves, Curvature and Radius of Curvature of a Curve in Cartesian, Parametric, Polar and Tangential Polar forms. [8L]

Module III

Functions of several variables: limit and continuity, partial derivatives. Euler's theorem, derivatives of composite and implicit functions, total derivatives, Errors and Approximations, Jacobian's. Taylor's and Maclaurin's expansion of functions of several variables, Maxima and minima of functions of several variables, Lagrange's method of undetermined multipliers. [9L]

Module IV

Definite Integral:

Reduction Formula, Differentiation under Integral Sign: Differentiation of Integrals with constant and variable limits, Leibnitz rule. [8L]

Improper integrals: convergence of improper integrals, test of convergence, Beta and Gamma Functions and its Properties, Error functions. [4L]

Module V

Application of Definite Integral:

Length of a Plane Curve, Area between Two Curves, Volume, Volume of Revolution, Area of Revolution, Work and Moments. [10L]

Textbooks:

1. H Anton, I Brivens, S. Davis : Calculus, 10^{th} Edition, John Wiley and sons, Singapore Pte. Ltd., 2013.
2. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus, 3^{rd} Ed, Dorling. Kindersley (India) Pvt. Ltd. (P Ed), Delhi, 2007.
3. M. D. Weir, J. Hass and F. R. Giordano: Thomas' Calculus, 11^{th} edition, Pearson Educations, 2008.

Reference Books:

1. Apostol: Calculus Vols 1 and 11.2nd Edition(reprint), John Wiley and sons, 2015.
2. Robert Wrede & Murray R. Spiegel, Advanced Calculus, 3rd Ed., Schaum's outline series, McGraw-Hill Companies, Inc.,2010.

COURSE INFORMATION SHEET

Course code: MA109
Course title: Matrix Theory
Pre-requisite(s): Basics of Algebra
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 lectures, 1 tutorial
Class: IMSc
Semester/level: I/1
Branch: Mathematics and Computing

Course objectives: This course enables the students to understand the

1.	different types of matrices and their properties.
2.	the rank of a matrix and apply it to solving system of linear equations.
3.	analyzing eigen values and associated eigen vectors of a matrix and their geometric interpretation and their various properties
4.	when a matrix is diagonalizable and how to diagonalise it.
5.	analyzing a real quadratic form and conclusion regarding its positivity or negativity.

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

CO1.	know about different types of matrices and their properties which are applicable to study other courses like algebra, vector analysis, cryptography, graph theory etc.
CO2.	evaluate the rank of a matrix and apply it to solve the system of linear equations, which are applicable to analyze the quantitative and qualitative properties of solutions of mathematical models in biological, ecological systems and in engineering problems.
CO3.	know about the various methods of solving system of linear equations, which are applicable to study the properties of solutions of different algebraic systems.
CO4.	Evaluate the eigen values and associated eigen vectors of a matrix and their geometric interpretation and their various properties, which are applicable to study the stability /instability nature of solutions of different algebraic systems.
CO5.	Theorems and properties related to function of matrix and its applications in different problems of computer graphics, electrical engineering, civil engineering, robotics and automation.

<u>**Syllabus**</u>

MA109 MATRIX THEORY 3-1-0-4

Module-I

Matrices, matrix operations, algebra of matrices, orthogonal, idempotent, nilpotent, involutory, Hermitian, Skew- Hermitian, unitary matrices and their properties, partition of matrices. [8L]

Module - II

Elementary operations, elementary matrices, inverse using elementary transformations, rank of a matrix, row-reduced echelon form, normal form, consistency of system of linear equations using rank (homogeneous and non - homogeneous).[9L]

Module - III

Solution to system of linear equations using gaussian elimination, Gauss – Jordan method, LU decomposition. Linear independence and dependence of vectors, introduction to linear transformations, matrix of linear transformation. [9L]

Module IV

Matric polynomials, characteristic equation, eigenvalues, eigenvectors, algebraic and geometric multiplicity of eigen values, diagonalization of matrices, orthogonal diagonalization, minimal polynomials. [10L]

Module V

Cayley-Hamilton theorem and its applications, real quadratic forms: definitions, examples of positive definite, positive semi definite, negative definite, negative semi definite and indefinite quadratic forms, rank, index and signature of quadratic forms. [9L]

Textbooks:

1. **S. Lipschutz, M. L. Lipson**: Schaum's Outline of Linear Algebra, McGraw-Hill, 2009.
2. **R.K Jain, S.R.K Iyengar**: Advanced Engineering Mathematics, Narosa Publication, 5th Ed., 2016
3. **David c. Lay**, Linear Algebra and its Applications (3rd Edition), Pearson Ed. Asia, Indian Reprint, 2007.

Reference book:

1. **S K Mapa**: Higher Algebra Abstract and Linear, Levant Publications., 2021
2. **B. V. Ramana**: Higher Engineering Mathematics, McGraw Hill, 2018

COURSE INFORMATION SHEET

Course code: MA102
Course title: Real Analysis
Pre-requisite(s): Basics of real number system, basics of algebra.
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 lectures, 1 tutorial
Class: IMSc
Semester/level: I/1
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	real number system and their properties
2.	open and closed sets, sequences and series
3.	convergence and divergence criteria for sequence and series of functions
4.	Riemann integration of real valued functions.
5.	fundamental theorem of calculus, mean value theorem of integral calculus

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

CO 1	understand the basic properties of real number system that will used later in development of real analysis theory.
CO 2	develop the logical thinking to proof the basic results of real analysis.
CO 3	solve the problems of convergence and divergence of sequences and series.
CO 4	develop an understanding of limits in abstract way and how they are used in sequences, series, differentiation and integration.
CO 5	appreciate how abstract ideas in real analysis can be applied to practical problems.

<u>Syllabus</u>

MA102 **Real Analysis** **3-1-0-4**

Module I
Axiomatic description of R, Archimedean property, Bounds: Supremum and infimum of a subset of R, Notion of neighborhood, interior point and limit point of a subset of R, open set and closed set together with their usual properties. [9L]

Module II
Monotonic sequence, limit of a sequence, convergent, divergent, and oscillating sequences, Lim sup and lim.inf. of sequences, Bolzano-Weierstrass theorem (Statement only), monotone convergence theorem, subsequence and Cauchy theorems on limit, Cauchy sequence, Nested interval theorem. [9L]

Module III
Convergence of series of real numbers of positive terms. P series test, comparison tests, Cauchy's root test, D' Alembert's ratio test, Raabe's test, Cauchy's Integral Test. Gauss's Ratio Test, Logarithmic and Higher Logarithmic Ratio Test, Absolute and conditional convergence, Leibnitz's Rule for Alternating series Test. [9L]

Module IV
Sequence of functions, uniform boundedness, pointwise and uniform convergence of sequence of functions, Series of functions, pointwise and uniform convergence of series of functions, Weierstrass-M Test. [8L]

Module V
Riemann integral, definition and existence of the integral, Upper and Lower Integrals, Darbous theorem, Properties of the integral, differentiation and integration, Fundamental theorem of integral calculus, Riemann integration of continuous and monotonic functions. Mean value theorems of integral calculus. [10L]

Textbooks:

1. N. P. Bali, Real Analysis, Firewall Media, Laxmi Publications Pvt. Ltd. 2009.
2. S.C. Malik, Principles of Real Analysis (Fourth Edition), New Age International publisher.

Reference Books:

1. Donald R. Sherbert and Robert G. Bartle, Introduction to Real Analysis, 2000
2. S. K. Mapa, Introduction to Real Analysis (Revised 6^{th} edition), Sarat book distributers, 2011.

COURSE INFORMATION SHEET

Course code: MA105R1
Course title: Calculus-II
Pre-requisite(s): Calculus-I
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures.
Class: IMSc
Semester/level: II/1
Branch: Mathematics and Computing

Course Objectives: This course is intended as a basic course to enable the students to get a detailed idea about:

1.	coordinate axes, coordinate plane and surfaces in 3-dimensional space
2.	the mathematical tools needed in evaluating multiple integrals and their usage.
3.	vector differential calculus
4.	vector integral calculus
5.	Vector-valued functions in orthogonal curvilinear coordinate system

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

CO1.	Explain coordinate axes and coordinate planes and surfaces in 3-dimensional space.
CO2.	visualize and deal with problems consisting of surface area volume of solids and derive different important quantities such as Centre of Mass and Moments.
CO3.	explain the characteristics of scalar and vector-valued functions, provide a physical interpretation of the gradient, divergence, curl, and related concepts, and also give an account of important vector field models of Nature.
CO4.	transform line integral to surface integral, surface to volume integral and vice versa using Green's theorem, Stoke's theorem, and Gauss's divergence theorem and understand the concept of vector-valued functions in orthogonal curvilinear coordinate system
CO5.	enhance and develop the ability to use the language of mathematics in analyzing the real-world problems of sciences and engineering.

Syllabus

MA105R1 Calculus-II 3-0-0-3

Module I

Three-dimensional space: rectangular coordinates in 3-D space, lines, planes, spheres, and cylinders. [8L]

Module II

Double and triple integrals, Iterated integrals and their connections, change of order of integration, Evaluation of area using double integrals, change of variables in double and triple integrals, Evaluation of volumes using double and triple integrals. [8L]

Module III

Calculus of scalar and vector point functions, Gradient, Directional derivative, Divergence and curl, properties, second-order derivatives, and identities. [8L]

Module IV

Line integrals, vector field, work, circulation, path independence, potential function, and conservative field. Surface integral, volume integral, Gauss, Green's and Stoke's theorems, application of vector calculus in engineering problems. [8L]

Module V

Transformation of coordinates, orthogonal curvilinear coordinates, Gradient, divergence, and curl in curvilinear co-ordinate systems, Special orthogonal curvilinear coordinate system: cylindrical, spherical. [8L]

Textbooks:

1. G.B. Thomas and R.L. Finney, Calculus and Analytic Geometry, 9th Edition, Pearson, Reprint, 2002.
2. M. D. Weir, J. Hass and F. R. Giordano: Thomas' Calculus, 11^{th} edition, Pearson Education, 2008.
3. H Anton, I Brivens, S. Davis: Calculus, 10^{th} Edition, John Wiley and Sons, Singapore Pvt. Ltd., 2013

Reference Books:

1. M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus (3rd Edition), Dorling Kindersley (India) Pvt.Ltd. (Pearson Education), Delhi, 2007.
2. Murray R Spiegel: Vector Analysis, Metric Editions, Schaum's Outline series.
3. Shanti Narayan, Analytic Solid Geometry, S. Chand & CO.
4. R.K. Jain and S.R.K. Iyengar, Advanced Engineering Mathematics, Narosa Publication.

COURSE INFORMATION SHEET

Course code: MA 110R1
Course title: COMPLEX ANALYSIS
Pre-requisite(s): Complex Numbers, Basic Calculus
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3 lectures
Class: IMSc
Semester / Level: II/1
Branch: Mathematics and Computing
Course Objectives: This course enables the students to understand the

1.	the strength of being analytic for a complex variable function and different properties associated with analytic functions
2.	the integration of complex variable functions and different techniques to evaluate complex integrals
3.	the series of complex variable functions, criteria for their convergence and divergence
4.	the singularities of complex variable functions and methods to compute residues
5.	mapping of complex variable functions and its different types

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

CO1.	demonstrate the remarkable properties of complex variable functions, especially of analytic functions
CO2.	develop an understanding related to integration of analytic complex variable functions, which are not the features of their real analogues
CO3.	conceptualize the infinite series of analytic complex variable functions and applying them to identify different types of singularities
CO4.	acquire the skills to employ the concept of residues in evaluating complex as well as some complicated real variable integrals
CO5.	understand complex variable elementary transformations and their properties

SYLLABUS

MA110R1 COMPLEX ANALYSIS 3-0-0-3

Module I

Function of a complex variable, Limit, continuity, differentiability and analyticity of complex variable functions, analytic functions, Cauchy – Riemann equations in cartesian and polar forms. [8L]

Module II

Integration of complex variable function**,** line integrals, properties of line integrals, Cauchy's theorem, Cauchy's Integral Formula, Cauchy's Integral formula for derivatives of analytic function. [8L]

Module III

Power Series, Taylor series, Laurent Series. Zeros and singularities of analytic function, types of singularities and their properties . [8L]

Module IV

Residues, computation of residues at poles, Cauchy – Residue theorem. Application of residue calculus in evaluation of real integrals of types $\int_0^{2\pi} f(\cos\theta, \sin\theta)d\theta$ and $\int_{-\infty}^{\infty} f(x)dx$ [8L]

Module V

Mappings (or Transformations) of complex variable functions, Conformal Mapping, Elementary transformations – translation, rotation, magnification, inversion, Bilinear transformation. [8L]

Textbooks:

1. J.W. Brown and R.V. Churchill, Complex Variable and its Applications, Tata McGraw Hill, Pub., 7th Edition, 2014.
2. D.G. Zill and P.D. Shanahan, A First Course in Complex Analysis with Applications, Jones and Bartlett Publishers, 2003
3. H.S. Kasana, Complex Variables: Theory and Applications, PHI, Second Edition, 2005.

Reference Books:

1. E. M. Stein and R. Shakarchi, Complex Analysis, Princeton University Press, 2003.
2. S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser, 2006.
3. M. R. Spiegel, S. Lipschutz, J.J. Schiller and D. Spellman, Complex Variables, Schuam Outlines, Tata McGraw Publications, 2nd Edition, 2009.

COURSE INFORMATION SHEET

Course code: MA 106R1
Course title: Ordinary Differential Equations
Pre-requisite(s): Differentiation, Integration.
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc
Semester / Level: II/1
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	first order linear and nonlinear differential equations and their solutions, trajectories and its types, Lagrange's equation, Clairaut's equation, envelopes
2.	existence and uniqueness theorem, Wronskian and its properties, higher-order linear differential equations with constant coefficients, method of variation of parameter
3.	simultaneous linear differential equations with constant coefficients, second order linear differential equations with variable coefficients,
4.	series solution of second-order linear differential equation. Solution of Bessel's and Legendre's equations.
5.	Initial value problems, Adjoint differential equations, Sturm-Liouville problem, eigenvalue and eigen function.

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

CO1	identify, analyze and subsequently solve physical situations whose behavior can be described by ordinary differential equations
CO2	competence in solving applied problems which are linear and nonlinear form
CO3	solve the problems choosing the most suitable method.
CO4	determine the solution of differential equations with initial and boundary value problems
CO5	enhance and develop the ability of using the language of mathematics in analyzing the real-world problems of sciences and engineering.

Syllabus

MA106R1 **Ordinary Differential Equations** **3-0-0-3**

Module I

First order linear and nonlinear differential equations and their solutions. Trajectories (Orthogonal, oblique, polar and Cartesian coordinate). Equations of first order but not of first degree and singular solutions: equation solvable for x and y, Lagrange's equation, Clairaut's equation, singular solutions (Envelopes). [8L]

Module II

Wronskian and linear dependence of functions, Abel's formula. Higher-order linear differential equations with constant coefficients, C.F and P.I. Euler-Cauchy equations. Method specific to second ODE: Methods of undetermined coefficients, reduction of order and Method of variation of parameters. [8L]

Module III

Simultaneous linear differential equations with constant coefficients, total differential equation, and condition of integrability. [8L]

Module IV

Series solution around an ordinary point and a regular singular point, the method of Frobenius. Bessel and Legendre equations. [8L]

Module V

Initial value problems: Picard's iteration method, Lipchitz condition, existence and uniqueness of solution of initial value problems for first order ODEs. Adjoint and Self-Adjoint differential equations, Sturm-Liouville problem, Eigen values and Eigen functions. [8L]

Textbooks:

1. G.F. Simmons: Differential Equations with Applications and Historical Notes, McGraw-Hill.
2. R. C. DiPrima and W. E. Boyce: Elementary Differential Equations and Elementary Differential with Boundary Value Problems, Willey.
3. Edwards & Penney: Differential Equations and Boundary value problems, Pearson Education
4. V. Sundarapandian: Ordinary and Partial Differential Equations with Laplace Transforms, Fourier Series and Applications, McGraw-Hill.

Reference books:

1. S.J. Farlow: An Introduction to Ordinary Differential Equations, PHI
2. M.D. Raisinghania: Ordinary and Partial Differential Equations, S. Chand & Co.
3. Erwin Kreyszig: Advanced Engineering Mathematics, Willey.

COURSE INFORMATION SHEET

Course code: MA202R1
Course title: Abstract Algebra
Pre-requisite(s):
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 3 lectures, 0 tutorial.
Class: IMSc.
Semester / Level: III/2
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	relation, mapping, equivalence relation and partition, residue class of integers, Chinese remainder theorem, partition of integer, primitive roots, binary operation, groups, permutation groups,
2.	subgroups, cyclic groups, cosets, normal, quotient group, homomorphism, Cayley's theorem, direct product of groups.
3.	conjugacy classes, Cauchy's theorem, p-groups, Sylow's theorem, solvable group, finitely generated abelian group, rings, subring, integral domains, ideals
4.	ring homeomorphisms, polynomial rings, factorization of polynomial, checking divisibility in integral domains, introduction to fields.
5.	divisibility in Integral Domains, prime and irreducible elements, concept and results about PID, ED and UFD.

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

CO1.	understand and apply number theory and special types of groups in discrete mathematics
CO2.	apply in various fields like computer science, cryptography, and coding theory. They provide a framework for understanding symmetry, transformations, and algebraic structures in different contexts
CO3.	demonstrate ability to think critically by recognizing patterns (like in Mathematical Crystallography) and principles of algebra and relating them to the number system and analyze them from abstract point of view.
CO4.	use applications in mathematics, science, engineering, and computer science. They provide a foundation for understanding algebraic structures, polynomial equations, and the properties of numbers and functions in various contexts.
CO5.	locate and use theorems to solve problems in number theory, use of ring theory to cryptography

Syllabus

MA202R1 Abstract Algebra 3-0-0-3

Module I

Primes, infinitude of primes, Fundamental theorem of arithmetic, congruence $a\,x \equiv b\,(\bmod n)$ Chinese remainder theorem, partition of integers, Euler ϕ-function, τ-function and Mobius inversion formula. Binary operations, introduction to groups (Symmetric group, Quaternion group, Dihedral group), subgroups, cyclic groups, cosets, and Lagrange's theorem. [8L]

Module II

Normal subgroup, quotient groups, simple group, homomorphism's and isomorphism's of group, permutation groups, Cayley's theorem, correspondence theorem and its corollary, direct products of groups. [8L]

Module III

Conjugacy classes, Cauchy's theorem and p-groups, Sylow's theorems and application. The finitely generated Abelian groups, fundamental theorem of finitely generated abelian group, invariant factors, elementary divisors. [8L]

Module IV

Introduction to rings, integral domain (I.D), and field. Sub rings and ideals intersection, union and sums of ideals, generating set of an ideal. Nilpotent ideal, Ring Homomorphism and fundamental theorem. Factor rings, prime ideal and maximum ideals. Basic theorems of isomorphism, embedding of field of quotients of an integral domain. [8L]

Module V

Divisibility in Integral Domains, prime and irreducible elements. Concept and results about PID, ED and UFD. Reducibility tests, irreducibility test, UFD in Z[x]). Polynomial Rings, division Algorithm of R[x], where R is commutative ring with unity. [8L]

Textbooks:

1. J.B. Fralieigh: A first Course in Abstract Algebra, Addison-Wesley
2. S.K. Mapa: Higher Algebra (Linear and Modern), Levant Publisher
3. V. K. Khanna & S.K. Bhambri: A Course in Abstract Algebra, Vikas Publishing House
4. I. N. Herstein: Topics in Algebra, Wiley

Reference Books:

1. S.K. Mapa: Higher Algebra (Linear and Modern), Levant Publisher
2. Joseph A.Gallian: Contemporary Abstract Algebra, Narosa Publishing House
3. A.K. Vasishtha & A.R. Vasishtha: Modern Algebra, Krishna Prakashan Media

COURSE INFORMATION SHEET

Course code: MA 201R1
Course title: Partial Differential Equation
Pre-requisite(s): Differentiation, Integration.
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 3 lectures.
Class: IMSc
Semester / Level: III/2
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	Origin of partial differential equations and their types, Lagrange's method, Cauchy's problem,
2.	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	identify, analyses and subsequently solve physical situations whose behaviour can be described by ordinary differential equations.
CO2	competence in solving applied problems which are linear and nonlinear form.
CO3	solve the problems choosing the most suitable method
CO4	determine the solutions of differential equations with initial conditions
CO5	determine the solutions of differential equations with initial and boundary conditions.

Syllabus

MA201R1 Partial Differential Equation 3-0-0-3

Module I

Formation of partial differential equations, definition and examples of linear and non-linear partial differential equations, order and degree of partial differential equations, linear partial differential equation of first order, equation solvable by direct integration, Lagrange's method, integral surfaces passing through a given curve, surfaces orthogonal to a given system of surfaces, and Cauchy's problem for first order partial differential equations. [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). [8L]

Module IV

Parabolic Equations: Solution of heat equation (separation method), 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, Neumann, Cauchy boundary conditions. Maximum and minimum principles, Dirichlet and Neumann problems for a rectangle (separation method), and theory of Green's function for Laplace equation. [8L]

Textbooks:

1. I. N. Sneddon: Elements of Partial Differential Equations, McGraw-Hill.
2. T. Amaranath: An Elementary Course in Partial differential equations, Narosa Publishing House.
3. S. L. Ross: Differential Equations, Wiley.
4. 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 INFORMATION SHEET

Course code: MA 206R1
Course title: Linear Algebra
Pre-requisite(s):
Credits: L:3 T: 0 P: 0 C:3
Class schedule per week: 3 lectures, 0 tutorial
Class: IMSc
Semester / Level: IV/2
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	basic ideas of vector algebra, linearly dependent and independent set, basis
2.	linear transformation, kernel and image, rank-nullity theorem, and its applications
3.	matrix representation of a linear transformation, change-of-basis (Transition) matrix. Eigenvalues and eigenvectors of linear operator
4.	eigenvalues of symmetric, skew symmetric, orthogonal and unitary matrices, diagonalization, triangular matrices, Jordan blocks and Jordon canonical form
5.	inner product spaces over R (real numbers) and C (complex numbers) their properties

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

CO1.	apply the theory of linear algebra to specific research problems in mathematics and engineering
CO2.	understand, analyze, and apply linear algebra concepts in various mathematical, scientific, and engineering contexts. These skills are fundamental in many areas of mathematics and its applications
CO3.	to analyze and solve a wide range of problems in mathematics, science, engineering, and computer science. These skills are essential for further studies in linear algebra and its applications.
CO4.	Use eigenvalues of matrices, diagonalization, triangular matrices, Jordan blocks and Jordon canonical form in many research areas.
CO5.	understand inner product spaces and their properties as they are crucial for various mathematical and scientific applications, enabling precise measurements and computations in a wide range of fields.

Syllabus

MA206R1 **Linear Algebra** **3-0-0-3**

Module I
Vector spaces, subspaces, linear combination, linear span, spanning sets, linear dependence and independence, Basis and dimension of a vector space, sums. [8L]

Module II
Linear transformation (L.T.), kernel and image, rank-nullity theorem and its applications, singular and non-singular L.T. [8L]

Module III
Matrix representation of a linear transformation, change-of-basis (Transition) matrix. Eigenvalues and eigenvectors, characteristic and minimal polynomials of linear operator. [8L]

Module IV
Eigenvalues of symmetric, skew symmetric, orthogonal and unitary matrices, Diagonalization and triangular form of matrices. Introduction to Jordan blocks and matrices in Jordon canonical form (examples only). An algorithm to find Jordan form of a square matrix (No proof). [8L]

Module V
Inner product spaces over R (real numbers) and C (complex numbers), Norm of a vector, Schwarz's Inequality, Triangle inequality, Orthogonality of vectors, orthogonal sets and basis, Parallelogram law, Bessel's inequality, Gram-Schmidt orthogonalization process, Orthogonal projection. [8L]

Textbooks:

1. K.M. Hoffmann and R. Kunze: Linear Algebra, Pearson Education
2. S. Lipschutz, M. L. Lipson: Schaum's Outline of Linear Algebra, McGraw-Hill
3. Stephen H. Friedberg, Lawrence E. Spence, Arnold J. Insel: Linear Algebra, Pearson

Reference Books
1. Gilbert Strang: Introduction to Linear Algebra, Wellesley-Cambridge press
2. Shanti Narayan and P.K Mittal: A textbook of Matrices, S. Chand.
3. S. K Mapa: Higher Algebra: Abstract and Linear, Algebra, Levant

COURSE INFORMATION SHEET

Course code: MA210
Course title: Discrete Mathematical Structure and Graph Theory
Pre-requisite(s): Basic Mathematics
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 03 Lectures, 1 Tutorial
Class: IMSc
Semester / Level: IV/2
Branch: Mathematics and Computing

Course Objectives: This course enables the students to

1.	exposed to a wide variety of mathematical concepts that are used in the Computer Science discipline, which may include concepts drawn from the areas of Number Theory, Graph Theory and Combinatorics.
2.	come across a number of theorems and proofs. Theorems will be stated and proved formally using various techniques.
3.	gain the various graphs algorithms along with its analysis
4.	apply graph theory-based tools in solving practical problems.

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

CO1.	understand and simplify basic logic statements, predicates and quantifiers and proofing methodologies.
CO2.	Understand different recurrence relations and method for solving them
CO3.	Understand the counting principles, searching and sorting algorithms
CO4.	understand the basic concepts in graph theory and would be able to apply in real world problems
CO5.	Understand the concepts of trees and apply the algorithms that are treated in the course for solving graph theoretical problems

Syllabus

MA 210 Discrete Mathematical Structure and Graph Theory 3-1-0-4

Module I

Introduction to Logic: Mathematical Logic and Mathematical Reasoning, Compound Statements, Truth tables, Propositional Equivalences, Predicates and Quantifiers, Methods of Proof, Validity of an Argument, Well Ordering Principle, Mathematical Induction. [9L]

Module II

Recursion: 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. [9L]

Module III

Principles of Counting and Algorithms: The Principle of Inclusion-Exclusion, The Addition and Multiplication Rules, The pigeon-hole Principle, Complexity, Searching and Sorting Algorithm, Enumeration of Permutations and Combinations. [9L]

Module IV

Introduction to Graph Theory: Introduction to Graph, Graph Terminologies and their Representation, Isomorphic Graph, Connected & Disconnected graphs, Euler & Hamiltonian graphs, Digraphs, Tournaments, Matrix Representation of Graphs and Digraphs, Scheduling Problems, Planar Graphs, Euler's formula, Graph colouring, Chromatic polynomial. [9L]

Module V

Trees and Searching: Definition, Rooted Tree, Binary Tree, Characterization and Simple Properties, Diameter of graph, Radius of graph, Center of graph, Spanning trees, Minimal Spanning trees, Kruskal's, Prim's and Dijkstra's Algorithms. [9L]

Textbooks:

1. Mott, Joe L., Abraham Kandel, and Theodore P. Baker Discrete Mathematics for Computer Scientists & Mathematicians, PHI, 2nd edition 2002.
2. Swapan Kumar Chakraborty and Bikash Kanti Sarkar: Discrete Mathematics, Oxford Univ. Publication, 2010.
3. Kolman, Bernard, Robert C. Busby, and Sharon Ross. Discrete mathematical structures, Prentice-Hall, Inc., 2003.
4. West, Douglas Brent. Introduction to graph theory. Vol. 2. Upper Saddle River: Prentice Hall, 2001.

Reference Books:

1. Arumugam, S. Invitation to graph theory. Scitech Publications Ind, 2006.
2. Balakrishnan, Rangaswami, and Kanna Ranganathan. A textbook of graph theory. Springer Science & Business Media, 2012.
3. Seymour Lipschuz and Mark Lipson, Discrete Mathematics, Shaum's outlines, 2003.
4. Liu, Chung Laung, Elements of Discrete mathematics, Mcgraw Hill, 2nd edition, 2001.
5. Bondy and Murty, Graph Theory with Applications, American Elsevier,1979.
6. Robin J. Wilson, Introduction to Graph Theory, Pearson, 2010.

COURSE INFORMATION SHEET

Course code: MA 311R1
Course title: Numerical Techniques
Pre-requisite(s):
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: V / 3
Branch: Mathematics and Computing

Course Objectives: This course enables the students to

1.	derive appropriate numerical methods to solve algebraic and transcendental equations
2.	learn appropriate numerical methods to solve linear system of equations and finding largest eigenvalue
3.	approximate a given function using various interpolation techniques
4.	to find the numerical solution of differentiation and definite integral
5	to find the numerical solution of initial value problems and boundary value problems

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

CO1	solve algebraic and transcendental equation using an appropriate numerical method arising in various engineering problems
CO2	solve linear system of equations using an appropriate numerical method arising in computer programming, chemical engineering problems etc.
CO3.	approximate a function using an appropriate numerical method in various research problems
CO4	evaluate derivative at a value using an appropriate numerical method in various research problems
CO5	solve differential equation with initial and boundary conditions numerically

Syllabus

MA311R1 **Numerical Techniques** 3-0-0-3

Module I

Definition and sources of errors, floating-point arithmetic and rounding errors. Solution of algebraic and transcendental equations: Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method and its variants, General iterative method and their convergence analysis. [8L]

Module II

Gauss-Elimination, Gauss-Jordan, LU-Decomposition, Cholesky, Gauss-Jacobi and Gauss-Seidel methods to solve linear system of equation. Error and convergence analysis of above methods. Power method to find least and largest eigenvalues. [8L]

Module III

Lagrange's interpolation, Newton's divided differences interpolation formulas, inverse interpolation, interpolating polynomial using finite differences, Piecewise interpolation, spline interpolation, B-splines, cubic splines.[8L]

Module IV

Differentiation using interpolation formulas. Integration using Newton-Cotes formulas (Trapezoidal rule, Simpson's 1/3, 3/8 rule, Weddle's rule) and their error analysis. [8L]

Module V

Euler's method, modified Euler's method, Runge-Kutta Methods of second and fourth order to solve initial value problems, finite difference methods for boundary value problems. [8L]

Textbooks:

1. Jain M.K.: Numerical Methods for Scientific and Engineering Computation, New Age Publication.
2. Sastry S.S.: Introductory Methods of Numerical Analysis, PHI

Reference Books

1. Chapra S.C. and Canale R.P.: Numerical Methods for Engineers, McGraw Hill
2. Hamming R.W.: Numerical Methods for Scientists and Engineers, Dover Publications

COURSE INFORMATION SHEET

Course code: MA 301R1
Course title: Probability and Statistics
Pre-requisite(s): NIL
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures.
Class: IMSc
Semester / Level: V/ 3
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	concepts in probability theory
2.	properties of probability distributions
3.	estimation of mean, variance and proportion
4.	concepts of statistical hypothesis

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

CO1	learn basic probability axioms, rules and the moments of discrete and continuous random variables as well as be familiar with common named discrete and continuous random variables.
CO2	derive the distribution of function of random variables,
CO3	how to derive the marginal and conditional distributions of random variables.
CO4	find the point and interval estimates, derive confidence intervals and understand the methods of estimation
CO5	analyse data statistically and interpretation of the results

Syllabus

MA301R1 **Probability and Statistics** **3-0-0-3**

Module I
Axioms of probability, Probability space, Conditional probability, independent events, Bayes' theorem, discrete and continuous random variables, Cumulative distribution function, probability mass and density functions, mathematical expectation, variance, moment generating function. [8L]

Module II
Discrete and continuous probability distributions such as Bernoulli, Binomial, Negative Binomial, Poisson, Uniform, Exponential, Beta, Gamma and Normal distribution, distribution of function of random variable. Covariance, Correlation and regression Analysis. [8L]

Module III
Joint distribution for two dimensional random variables, marginal distributions, conditional distributions, conditional expectation, conditional variance, independence of random variables, distribution of sum of two independent random variables. The Central Limit Theorem, t-distribution, Chi-Square Distribution, F- Distribution. [8L]

Module IV
Point Estimation and Interval Estimation, Interval Estimation of three Common Parameters: mean, variance and proportion. The method of moments and the method of maximum likelihood estimation, confidence intervals for the mean(s) and variance(s) of normal populations. [8L]

Module V
Testing of Statistical hypothesis: Null and alternative hypotheses, the critical and acceptance regions, two types of error, tests involving a population mean, tests involving a population proportion, tests involving a population variance, tests for two population means, tests for two population proportions, tests for two population variances. [8L]

Textbooks:

1. Johnson R.A, Miller I. and Freund J.: Probability and Statistics for Engineers, PHI
2. Hogg, R.V. and Tanis E.A.: Probability and Statistical Inference, Pearson
3. Pal N. and Sarkar S.: Statistics: Concepts and Applications, PHI
4. Gupta S.C and Kapoor V.K.: Fundamental of Mathematical Statistics, Sultan Chand and Sons.
5. Walpole, R.E., Myers, R.E., Myers R.H., Myers S.L. and Ye K.: Probability for Statistics and Engineers, Pearson

Reference Books:

1. Feller W.: Introduction to Probability theory and applications, John Wiley
2. Freund J.E.: Mathematical Statistics, Pearson
3. Meyer P.L.: Introductory Probability and Statistical Applications, Oxford & IBH,
4. Hines W., Montgomery D., Goldsman, D. and Borror, C.: Probability & Statistics in Engineering, John Wiley

COURSE INFORMATION SHEET

Course code: MA312R1
Course title: Numerical Techniques Lab
Pre-requisite(s):
Credits: L: 0 T: 0 P: 2 C:1
Class schedule per week: 02 Sessional.
Class: IMSc.
Semester / Level: V/ 3
Branch: Mathematics and Computing

Course Objectives: This course enables the students to

1.	execute appropriate numerical methods to solve algebraic and transcendental equations correct up to some certain level of significance
2.	solve linear system of homogenous and non - homogeneous equations in computer
3.	approximate a function by polynomial using various interpolation techniques
4.	compute numerical solution of initial value problems and boundary value problems
5.	handle numerical problems efficiently by programming language like C, C++ on computer

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

CO1	solve algebraic and transcendental equation using an appropriate numerical method arising in various engineering problems efficiently
CO2	solve linear system of equations using an appropriate numerical method arising in computer programming, chemical engineering problems etc efficiently
CO3.	approximate a function using an appropriate numerical method in various research problems up to desired level of accuracy
CO4	evaluate definite integral using an appropriate numerical method in various practical problems
CO5	solve different types of differential equations numerically

Syllabus

MA312R1 Numerical Techniques Lab 0-0-2-1

1. Find a simple root of $f(x) = 0$ using bisection method. Read the end points of the interval (a, b) in which the root lies, maximum number of iterations n and error tolerance eps.
2. Find a simple root of $f(x) = 0$ using Regula-Falsi method and Secant method. Read the end points of the interval (a, b) in which the root lies, maximum number of iterations n and error tolerance eps.
3. Find a simple root of $f(x) = 0$ using Secant method. Read the end points of the interval (a, b) in which the root lies, maximum number of iterations n and error tolerance eps.

4. Find a simple root of $f(x) = 0$ using Newton Raphson method. Read any initial approximation x_0, maximum number of iterations n and error tolerance eps.
5. Solution of a system of $n \times n$ linear equations using Gauss elimination method without and with partial pivoting.
6. Matrix inversion and solution of a system of $n \times n$ linear equations using Gauss-Jordan method.
7. Solution of a system of $n \times n$ linear equations using LU decomposition.
8. Program to solve a system of equation using Gauss-Seidel and Jacobi iteration method. Order of the matrix is$n$, maximum number of iterations no of iteration $niter$, error tolerance is eps and the initial approximation to the solution vector is x_0.
9. Program to find the largest eigenvalue of a square matrix using power method.
10. Program for Lagrange and Newton divided difference interpolation.
11. Program for Newton's forward and backward interpolation.
12. Program to evaluate the integral of $f(x)$ between the limits a to b using Trapezoidal rule of integration based on $n$subintervals or $n + 1$ nodal points. The values of a, b and n are to be read.
13. Program to evaluate the integral of $f(x)$ between the limits a to $b$using Simpson's rule of integration based on $2n$ subintervals or $2n + 1$ nodal points. The values of a, b and n are to be read and the integrand is written as a function subprogram.
14. Program to solve an IVP, $\frac{dy}{dx} = f(x, y), y(x_0) = y_0$ using Euler method. The initial value x_0, y_0 the final value x_f and the step size h are to be read. The program is tested for $f(x, y) = -2xy^2$.
15. Program to solve an IVP, $\frac{dy}{dx} = f(x, y), y(x_0) = y_0$ using the classical Runge-Kutta fourth order method with step size $h, h/2$ and also computes the estimate of the truncation error. Input parameters are: initial point, initial value, number of intervals and the step length h. Solutions with size $h, h/2$ and the estimate of the truncation error are available as output. The right hand side The program is tested for $f(x, y) = -2xy^2$.

Textbooks:

1. Jain M.K.: Numerical Methods for Scientific and Engineering Computation, New Age Publication.
2. Sastry S.S.: Introductory Methods of Numerical Analysis, PHI
3. Yashavant Kanetkar: Let Us C, BPB Publications

Reference Books

4. Chapra S.C. and Canale R.P.: Numerical Methods for Engineers, McGraw Hill
5. Hamming R.W.: Numerical Methods for Scientists and Engineers, Dover Publications

COURSE INFORMATION SHEET

Course code: MA303R1
Course title: FUZZY LOGIC
Pre-requisite(s): A basic knowledge of set theory
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: V/3
Branch: Mathematics and Computing

Course Objectives: The course objective is to

1.	familiarize the students with the fundamentals of fuzzy sets, operations on these sets and concept of membership function.
2.	familiar with fuzzy relations and the properties of these relations
3.	know the concept of a fuzzy number and how it is defined. Become aware of the use of fuzzy inference systems in the design of intelligent systems.
4.	apply fuzzy linear programming in real life problems in various area of research.

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

CO1	be able to distinguish between the crisp set and fuzzy set concepts through the learned differences between the crisp set characteristic function and the fuzzy set membership function.
CO2	become familiar with fuzzy relations and the properties of these relations.
CO3	know the concept of a fuzzy number and apply in real world problems.
CO4	capable of drawing a distinction between binary logic and fuzzy logic at the conceptual level, representing a simple classical proposition using crisp set characteristic function and representing a fuzzy proposition using fuzzy set membership function. knowledgeable of conditional fuzzy propositions and fuzzy inference systems and aware of the use of fuzzy inference systems in the design of intelligent systems.
CO5	apply fuzzy linear programming in real life problems like inventory control etc.

Syllabus

MA303R1 **Fuzzy Logic** **3-0-0-3**

Module I

Classical sets: operations on classical (crisp) sets, Properties of classical sets, Mapping of classical sets to functions. Fuzzy Sets: Basic Fuzzy set operations, Properties of Fuzzy sets. Representation of Fuzzy Sets, Types of Membership Function, Development of Membership Functions. Properties of membership functions. [8L]

Module II

Crisp Relations: cartesian product, other crisp relations, operations on Relations. The Extension Principle for fuzzy sets. Fuzzy Relations: Fuzzy Cartesian product, operations of Fuzzy relations. Compositions of Fuzzy Relations, Properties of the Min-Max Composition. [8L]

Module III

Fuzzy Arithmetic: Fuzzy Numbers, Linguistic Variables, Arithmetic operations on interval, arithmetic operations on fuzzy numbers, Algebraic Operations with Fuzzy Numbers, Lattice of Fuzzy Numbers. [8L]

Module IV

Crisp logic: Law of Propositional logic, Inference in Propositional Logic. First Order Predicate Logic, Predicate Logic: Interpretation of Predicate Logic Formula, Inference in Predicate Logic. Fuzzy Logic: Fuzzy Quantifiers, Fuzzy Inference. Fuzzy Rule based system. Defuzzification Methods. [8L]

Module V

Decision Making in Fuzzy Environment: Fuzzy Decisions, Fuzzy Linear Programming, Symmetric Fuzzy LP, Fuzzy LP with crisp objective Function. Application: Fuzzy sets model in inventory control. [8L]

Textbooks:

1. Timothy J. Ross, Fuzzy Logic with Engineering Applications, Wiley, India.
2. George J. Klir /Bo Yuan, Fuzzy Sets and Fuzzy Logic, Theory and Applications, PHI learning private Limited.

Reference Books:

1. H.-J. Zimmermann, Fuzzy Set Theory and its Application, Kluwer Academic Publishers.
2. John Yen and Reza Langari, Fuzzy Logic: Intelligence, Control and information, Pearson Education.

COURSE INFORMATION SHEET

Course code: MA208R1
Course title: Integral Transform and Applications
Pre-requisite(s): Some background in Ordinary and partial differential
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 03 Lectures
Class: IMSc
Semester / Level: V/ 3
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	key concept of popular and useful transformations techniques like; Laplace and inverse Laplace transform, Fourier transform, Hankel transform and Z-transform. with its properties and applications.
2.	basic knowledge to solve ordinary and partial differential equations with different forms of initial and boundary conditions.

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

CO1.	understand the key concept of popular and useful transformations techniques like; Laplace and inverse Laplace transform, Fourier transform, Hankel transform and Z-transform.
CO2.	apply the knowledge of Laplace transform and its inverse to solve ordinary and partial differential equations with different forms of initial and boundary conditions.
CO3.	apply the knowledge of Fourier and Hankel transform and its inverse to solve various boundary value problems of science and engineering.
CO4.	apply the knowledge of Z transform and its inverse to solve research problems of signal processing, data analysis and processing, image processing, in scientific simulation algorithms etc.
CO5.	solve the complex mathematical problems using the knowledge of different transform.

Syllabus

MA 208R1 — Integral Transform and its Applications — 3-0-0-3

Module I

Periodic Functions, Euler's formula, Dirichlet's conditions, Fourier series of functions with arbitrary period, expansion of even and odd functions, Half- range series, Parseval's formula, complex form of Fourier series. [6L]

Module II

Definition, linearity property, sufficient conditions for existence of Laplace transform, shifting properties, Laplace transform of derivatives, integrals, unit step functions, Dirac delta-function, impulse and periodic function. Inverse Laplace transforms convolution theorem and inversion formula. Application of Laplace transform for solving ODEs, PDEs (Hyperbolic and parabolic types). [10L]

Module III

Fourier Integral formula, Fourier Transform, Fourier sine and cosine transforms. Linearity, Scaling, frequency shifting and time shifting properties. Self-reciprocity of Fourier transform, convolution theorem. Application for solving PDEs (Hyperbolic and parabolic types). [8L]

Module IV

Definition and elementary properties: inversion theorem, Henkel transforms of derivatives, Parseval's theorem. Application for solving boundary value problems, and partial differential equations. [8L]

Module V

Linear difference equations, Fibonacci relation, basic theory of Z-Transforms, Existence of Z-Transforms, Linearity property, translation and shifting theorems, scaling properties, convolution theorem, inverse of Z -Transform. [8L]

Textbooks:

1. **Lokenath Debnath, Dambaru Bhatta**: Integral Transforms and their Applications, CRC Press Taylor & Francis Group, 3rd edition, 2015.
2. **R.K Jain, S.R.K Iyengar**: Advanced Engineering Mathematics, Narosa Publication, 5thEd., 2016
3. **M.D. Raisinghania**: Ordinary and Partial Differential Equations, S.Chand & Co., 9thEd., 2017
4. **Erwin Kreyszig**: Advanced Engineering Mathematics, John Wiley & Sons, Inc., 9th Edition,2006.

Reference Books:

1. **K. Sankara Rao**: Introduction to Partial Differential Equations, PHI Learning
2. **Vasishtha & Gupta**: Integral Transforms, Krishna Prakashan, Meerut.
3. **B. V. Ramana**: Higher Engineering Mathematics, McGraw Hill

COURSE INFORMATION SHEET

Course code: MA315R1
Course title: Financial Mathematics
Pre-requisite(s): Probability and Random variable
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures, 0 tutorial
Class: IMSc
Semester/level: V/3
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	basic securities, organization of financial markets, the concept of interest rates, present and future value of cash flow.
2.	basic property of option, no arbitrage principle, short selling, put-call parity.
3.	concept of option pricing using single and multi-period binomial pricing models and the limiting case of Cox-Ross-Rubinstein (CRR) Model as a famous Black-Scholes formula for option pricing.
4.	derivatives forwards, futures and swaps and their pricing.
5	portfolio construction at the overall plan level, taking into account investor objectives and the practical challenges of implementation.

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

CO1	describe and explain the fundamental features of a *financial* instruments.
CO2	understand difference between the risky and risk-free assets.
CO3	acquire knowledge of how forward contracts, futures contracts, swaps and options work, how they are traded and how they are priced.
CO4	evaluate the price of option using Binomial model.
CO5	demonstrate a clear understanding of financial research planning, methodology and implementation.

Syllabus

MA315R1 **Financial Mathematics** **3-0-0-3**

Module I
Overview of Financial Engineering: Financial markets and instruments, interest rates, present and future values of cash flows, risk-free and risky assets. [8L]

Module II
Options: call option, put option, expiration date, strike price/exercise price, European, American option and exotic options, put-call parity, a basic property of options. [8L]

Module III
Basic theory of option pricing: single and multi-period binomial pricing models, Cox-Ross-Rubinstein (CRR) model, American option in binomial model, Black-Scholes formula for option pricing as a limit of CRR Model. [8L]

Module IV
Forwards, futures and swaps: forward and futures contract, pricing of forward and futures, swaps, plain vanilla interest rate swaps, currency swaps, pricing swaps, pricing a commodity swap, pricing an interest rate swap. [8L]

Module V
Mean-variance portfolio theory: Markowitz model of portfolio optimization and capital asset pricing Model (CAPM). [8L]

Textbooks:
1. J Cvitanic and F. Zapatero, Introduction to the Economics and Mathematics of Financial Markets, Prentice. -Hall of India, 2007.
2. M. Capinski and T. Zastawniak, Mathematics for Finance: An Introduction to Financial Engineering, 2nd Ed., Springer, 2010.
3. J. C. Hull, Options, Futures and Other Derivatives, 8th Ed., Pearson India/Prentice Hall, 2011.

Reference books:
1. S. Roman, Introduction to the Mathematics of Finance: From Risk Management to Options Pricing, Springer India, 2004.
2. S. R. Pliska, Introduction to Mathematical Finance: Discrete Time Models, Blackwell, 1997.
3. S. N. Neftci, Principles of Financial Engineering, Academic Press/Elsevier India, 2009.

COURSE INFORMATION SHEET

Course code: MA 209R1

Course title: Integral Equations and Green's Function

Pre-requisite(s): Laplace Transform, Ordinary Differential Equation and Partial Differential Equation, Basic Linear Algebra.

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

Class schedule per week: 3 Lectures

Class: IMSc

Semester/level: V/3

Branch: Mathematics and Computing

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

1.	the integral equation, its classification, different types of kernels.
2.	the relationship between the integral equations and ordinary differential equations and how to solve the linear and nonlinear integral equations by different methods with some problems which give rise to integral equations.
3.	how to solve Fredholm integral equation with separable kernel and how to reduce homogeneous Fredholm integral equation to Sturm-Liouville problem and solve it as eigen value and eigen vector problem.
4.	different types of solution methods like successive approximation, resolvent kernel, iteration method, integral transform method and which method is applicable for which type of integral equation.
5.	the Green function and its construction and its application in solving boundary value problem by converting it to a integral equation.

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

CO1.	acquire sound knowledge of different types of Integral equations: Fredholm and Volterra integral equations etc. and derive integral equation from ODE and PDE arising in different branches of science and engineering.
CO2.	solve Fredholm integral equation with separable kernel and reduce homogeneous Fredholm integral equation to Sturm-Liouville problem and solve it as eigen value and eigen function problems.
CO3.	acquire sound knowledge of different types of solution methods like successive approximation, resolvent kernel, iteration method.
CO4.	acquire sound knowledge about fundamental properties of eigenvalues and eigenfunctions for symmetric kernels and about the method of solution of symmetric integral equation.
CO5.	construct Green function in solving BVP and IVP by converting it into integral equations and apply the knowledge of integral transformation to solve the complex mathematical problems involving of Integral equations.

Syllabus

MA209R1	**Integral Equations and Green's Function**	**3-0-0-3**

Module I

Definition, classification of integral equation, types of kernels, solution of integral equation. Leibnitz's rule of differentiation under integral sign, identity for converting multiple integral into single integral. Conversion of IVPs into Volterra integral equation, BVPs into Fredholm integral equation. [8L]

Module II

Fredholm integral equations with separable (degenerate) kernels and its solution. Fredholm theorem. Eigenvalues and eigenfunctions of homogeneous Fredholm integral equation of second kind with separable or degenerate kernels. [8L]

Module III

Method of successive approximation: Iterated kernels, Resolvent kernel. Solution of Fredholm and Volterra equation of second kind by successive substitutions. (method of iteration). Solution of Fredholm and Volterra equation of second kind by successive approximations. Method of iteration. Neumann Series. Solution of Volterra integral equation by reducing into differential equation. Solution of Volterra integral equation of first kind.[8L]

Module IV

Symmetric kernel, orthonormal system of function, fundamental properties of eigenvalues and eigenfunctions for symmetric kernels, expansion of symmetric kernel in eigen function. Hilbert-Schmidt theorem, solution of symmetric integral equation by Hilbert- Schmidt theorem. [8L]

Module V

Construction of Green's function, existence and uniqueness theorem, conversion of BVPs into Fredholm integral equation and IVPs into Volterra integral equation by Green's function. Solution of Volterra integral equation with convolution type kernel, integro-differential equation, Abel's integral equation by Laplace and Fourier transform methods. [8L]

Textbooks:

1. David Porter, David S.G. Stirling: Integral Equation, Cambridge Texts in Applied Mathematics.
2. M.D. Raisinghania: Integral Equations and Boundary Value Problems, 2016.

Reference Book:

1. C. S. Manjarekar, Integral Equation, 2^{nd} Edition, 2015.

COURSE INFORMATION SHEET

Course code: MA 309R1
Course title: Optimization Techniques
Pre-requisite(s):
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures, 0 Tutorial
Class: IMSc.
Semester / Level: VI / 3
Branch: Mathematics and Computing

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

1	Mathematical Formulation of LPP, Solution of LPP: Graphical Method, Simplex Method, Big-M Method, Two Phase method, Duality theory, Dual Simplex algorithm, Post-optimal Analysis.
2	Solution of Transportation problem: Initial Basic Feasible Solution by North-West Corner Method, least Cost, Vogel Approximation Method. Optimal solution by MODI Method. Assignment Model: Hungarian Method.
3	Revised Simplex Method, Parametric Linear Programming, Integer Linear Programming: Branch and Bound Method, Cutting Plane Method.
4	Network and basic components, Determination of critical path: Critical Path Method (CPM), Project Evaluation and Review Techniques (PERT).
5	Problem of Sequencing, Processing n Jobs through Two Machines, Processing n Jobs through 3 Machines and Processing n Jobs through k Machines.

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

CO1	Formulate an LPP and solve it by simplex and graphical method. Also do post optimal analysis of the formulated problem or other application areas.
CO2	To be able to solve a Transportation and Assignment problem.
CO3	To be able to use advanced LPP in his or her application area.
CO4	Fundamentals of Network Analysis using CPM and PERT.
CO5	Solve a sequencing Problem for various jobs and machines.

Syllabus

MA309R1 **Optimization Techniques** **3-0-0-3**

Module I

Linear Programming Problem (LPP): Mathematical Formulation of LPP, Solution of LPP: Graphical Method, Simplex Method, Big-M Method, Two Phase method, Duality theory, Dual Simplex algorithm, Post-optimal Analysis. [8L]

Module II

Transportation and Assignment Models: Solution of Transportation problem: Initial Basic Feasible Solution by North-West Corner Method, least Cost, Vogel Approximation Method. Optimal solution by MODI Method. Assignment Model: Hungarian Method. [8L]

Module III

Advanced Linear Programming: Revised Simplex Method, Parametric Linear Programming, Integer Linear Programming: Branch and Bound Method, Cutting Plane Method. [8L]

Module IV

Network Analysis (CPM and PERT): Network and basic components, Determination of critical path: Critical Path Method (CPM), Project Evaluation and Review Techniques (PERT). [8L]

Module V

Sequencing Problem: Problem of Sequencing, Processing n Jobs through Two Machines, Processing n Jobs through 3 Machines and Processing n Jobs through k Machines. [8L]

Textbooks:

1. Hamdy A Taha: Operations Research, Pearson Education.
2. Kanti Swarup, P. K. Gupta and Manmohan: Operations Research, Sultan Chand & Sons.

Reference Books:

1. Hiller and Lieberman: Operation Research, McGraw Hill.
2. J. K. Sharma: Operations Research: Theory and applications, Mac-Millan Publishers.
3. S. S. Rao: Engineering Optimization: Theory and Practice, Fourth Edition, John Wiley, and Sons.
4. R. K. Gupta: Operations Research, Krishna Prakashan Media Pvt.Ltd.

COURSE INFORMATION SHEET

Course code: MA 310R1
Course title: Optimization Techniques Lab
Pre-requisite(s):
Credits: L: 0 T: 0 P: 2 C:1
Class schedule per week: 3 Sessional
Class: IMSc.
Semester / Level: VI / 3
Branch: Mathematics and Computing

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

1	Mathematical Formulation of LPP, Solution of LPP: Graphical Method, Simplex Method, Big-M Method, Two Phase method, Duality theory, Dual Simplex algorithm, Post-optimal Analysis.
2	Solution of Transportation problem: Initial Basic Feasible Solution by North-West Corner Method, least Cost, Vogel Approximation Method. Optimal solution by MODI Method. Assignment Model: Hungarian Method.
3	Revised Simplex Method, Parametric Linear Programming, Integer Linear Programming: Branch and Bound Method, Cutting Plane Method.
4	Network and basic components, Determination of critical path: Critical Path Method (CPM), Project Evaluation and Review Techniques (PERT).
5	Problem of Sequencing, Processing n Jobs through Two Machines, Processing n Jobs through 3 Machines and Processing n Jobs through k Machines.

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

CO1	formulate an LPP and solve it by simplex and graphical method. Also, do post optimal analysis of the formulated problem or other application areas.
CO2	be able to solve a Transportation and Assignment problem.
CO3	be able to use advanced LPP in his or her application area.
CO4	fundamentals of Network Analysis using CPM and PERT.
CO5	solve a sequencing Problem for various jobs and machines.

List of Assignments

1. Solving by graphical method (including special cases) the LPP using TORA.
2. Solve by simplex method the LPP by LINGO & TORA only.
3. Solve by BIG- method the LPP by LINGO & TORA only.
4. Solve by Two-Phase Method by LINGO& TORA only.
5. Solve an LPP by dual simplex method by TORA only.
6. Solve the integer Programming Problem (Branch and Bound Method) by TORA and LINGO.
7. Solve the Transportation problem by LINGO & TORA only.
8. Solve the minimal spanning tree problem using TORA.
9. Solve the shortest route problem using TORA only.
10. Solve the minimal flow problem using TORA only.
11. Solve the Critical Path (CPM) Problem using TORA only.
12. Solve the PERT problem using TORA only.

Textbooks:

1. Hamdy A Taha: Operations Research, Pearson Education.
2. Kanti Swarup, P. K. Gupta and Manmohan: Operations Research, Sultan Chand & Sons.

Reference Books:

1. Hiller and Lieberman: Operation Research, McGraw Hill.
2. J. K. Sharma: Operations Research: Theory and applications, Mac-Millan Publishers.
3. S. S. Rao: Engineering Optimization: Theory and Practice, Fourth Edition, John Wiley and Sons.
4. R. K. Gupta: Operations Research, Krishna Prakashan Media Pvt. Ltd.

COURSE INFORMATION SHEET

Course code: MA 307
Course title: Computational Linear Algebra
Pre-requisite(s): Basics of differential Calculus and integral Calculus
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 Lectures
Class: IMSc.
Semester/level: VI /3
Branch: Mathematics and Computing

Course Objectives: This course is intended as a basic course enables the students to get the detailed idea about:

1.	various methods and iterative process to solve linear system of equations
2.	the fundamental properties of eigenvalues, eigenvectors of matrix theory
3.	the principles behind the iterative algorithms for computing eigenvalues
4.	the basic ideas of QR algorithm

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

CO1	apply the computational techniques and algebraic skills to various types of research problems science and engineering
CO2	transform matrices into triangular, Hessenberg, tri-diagonal, or unitary form using elementary transformations arising from ODEs and PDEs
CO3	locate and estimate the eigenvalues of a square matrix using Gerschgorin bounds, power method, Rayleigh quotient iteration
CO4	compute the SVD, polar decomposition of singular matrices
CO5	apply various direct and iterative method to solve the system of equations.

Syllabus

MA307 Computational Linear Algebra 3-0-0-3

Module I

Basic concept of a linear system of equations. Direct methods: Gauss elimination method, partial and complete pivoting, Gauss-Jordan method, LU decompositions, Cholesky method, Partition method, Vector and matrix norms, condition numbers, estimating condition numbers, significant digit, floating point arithmetic, analysis of round off errors. [8L]

Module II

Iterative methods: General iteration method, Jacobi and Gauss-Seidel iteration methods, Successive over relation method (SOR), convergence analysis of iterative methods and optimal relaxation parameter for the SOR method. [8L]

Module III

Gram-Schmidt orthonormal process, orthogonal matrices, Householder transformation, Givens rotations, QR factorization, round off error analysis of orthogonal matrices, stability of QR factorization. [6L]

Module IV

Solution of linear least squares problems, singular value decomposition (SVD), polar decomposition, Moore-Penrose inverse and rank deficient least squares problems. Reduction to Heisenberg and tri-diagonal forms. [6L]

Module V

Eigen values and Eigen vectors: Bounds on eigenvalues, Gerschgorin bounds, Jacobi, Givens, Householder's methods for symmetric matrices. Dominant and smallest Eigen values/Eigen vectors by power method, Rayleigh quotient iteration, explicit and implicit QR algorithms for symmetric and non-symmetric matrices, implementation of implicit QR algorithm, computing the SVD, sensitivity analysis of singular values and singular vectors, the Arnoldi and the Lanczos iterations. [12L]

Textbooks:

1. G.W. Stewart: Introduction to Matrix Computations, Academic Press.
2. M.K. Jain, S.R.K. Iyengar, R.K. Jain: Numerical Methods, Problems and Solutions, New Age International.
3. S.S. Sastry: Introductory Methods of Numerical Analysis, PHI learning.
4. C. L. Byrne: Applied and Computational Linear Algebra, A First Course, CRC

Reference Books:

1. G.H. Golub, C. F. Van Loa: Matrix Computation, John Hopkins U. Press, Baltimore
2. J.W. Demmel: Applied Numerical Linear Algebra, SIAM, Philadelphia
3. D.S. Watkins: Fundamentals of Matrix Computations, Willey

COURSE INFORMATION SHEET

Course code: MA 308
Course title: Difference Equations
Pre-requisite(s): Sequence and Series of numbers and functions.
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: VI/ 3
Branch: Mathematics and Computing
Course Objectives: This course enables the students to understand the

1	application of sequences and series of numbers and functions.
2	partial difference equations
3.	Discrete boundary value problem.
4.	Application with different engineering problem.
5.	Discrete mathematical models.

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

CO1.	apply the theory to study the qualitative theory of solutions of difference equations and partial difference equations of higher order.
CO2.	Apply the theory to study the quantitative and qualitative study of solutions of different discrete models in Engineering and Biology and Ecology.
CO3.	Difference between the qualitative and quantitative behaviour of solutions of the difference equations and the corresponding differential equations.
CO4	Apply the theory to study the solution in discrete boundary value problems.
CO5	Under discrete population dynamics.

Syllabus

MA308 **Difference Equations** **3-0-0-3**

Module 1

The Difference Calculus: Genesis of difference equations, Definitions, derivation of difference equations, existence and uniqueness theorem, Operators Δ and E, Elementary difference operators, factor polynomials, Operator Δ^{-1} and the sum calculus. [8L]

Module II

First Order difference equations: Introduction, General linear equations with examples, equations of the forms $y_{k+1} = R_k y_k$ and $y_{k+1} - y_k = (n+1)k^n$ with examples, Continued fractions, A general first-order equations: Geometrical methods and expansion techniques. [8L]

Module III

Linear Difference equations: Introduction, Linearly dependent functions, fundamental theorem for homogeneous equations, Inhomogeneous equations, second order equations, Sturm-Liouville difference equations. [8L]

Module IV

Linear Difference equations (Contd…): Homogeneous equations: Construction of difference equation having specified solutions, relationship between linear difference and differential equations.

Inhomogeneous equations: Method of undetermined coefficients and separation method. The z-transform method. [8L]

Module V

Linear Partial Difference equations: Introduction, symbolic methods, Lagrange's and separation of variables, Laplace method, Particular solution, Simultaneous equations with constant coefficients.[8L]

Textbooks:

1. R. E. Mickens, Difference Equations: Theory, Applications and Advanced Topics, CRC Press, Third Edition, 2015.

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

COURSE INFORMATION SHEET

Course code: MA 316R1
Course title: Statistical Quality Control and Reliability
Pre-requisite(s): Basics of statistics and probability
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures, 0 tutorial.
Class: IMSc
Semester / Level: VI/3
Branch: Mathematics and Computing

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

1.	Meaning and uses of statistical quality control (SQC)
2.	Real life industrial applications of different control charts
3.	Real life industrial applications of different sampling inspection plans
4.	Reliability functions for several time to failure probability distributions
5.	Hypothesis testing in the context of reliability

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

CO1	apply the concept of SQC in business and industrial applications
CO2	prepare appropriate control charts both for qualitative and quantitative characteristics
CO3	design an appropriate sampling inspection plan for a real life problem
CO4	choose an appropriate time to failure probability distribution and estimate its reliability for complete and censored samples
CO5	set up and test an appropriate hypothesis in the context of reliability; also compute confidence intervals

Syllabus

MA316R1 Statistical Quality Control and Reliability 3-0-0-3

Module I

Meaning and uses of SQC, chance and assignable causes of variation, process and product control, control charts, Chebyshev inequality and its applications in SQC, 3σ and 6σ limits. **[8L]**

Module II

Control charts for quantitative characteristics, mean and range chart, standard deviation or σ chart, Control charts for qualitative characteristics, p chart, d chart, control chart for number of defects per unit (c chart), cumulative sum (CUSUM) chart modified control chart. **[8L]**

Module III

Acceptance Quality Level (AQL), Lot Tolerance Proportion Defective (LTPD), Process Average Fraction Defective (PAFD), Consumer's risk, Producer's risk, Rectifying Inspection Plans, Average Outgoing Quality Limit (AOQL), Operating Characteristic (OC) curve, Average Sample Number (ASN), Dodge and Romig rectifying sampling inspection plans, single sampling, double sampling plan, sequential sampling. **[8L]**

Module IV

Reliability function, Applications of Exponential, Gamma, normal, lognormal, Weibull distributions in reliability and estimation of their parameters, reliability estimation with complete and censored samples. **[8L]**

Module V

Testing of hypothesis and confidence intervals in the context of reliability; reliability of series, parallel and standby systems. **[8L]**

Textbooks:

1. S.C. Gupta and V. K. Kapoor, Fundamentals of Applied Statistics, Sultan Chand & Sons, 2002
2. S. K. Sinha and B. K. Kale, Life Testing and Reliability Estimation, Wiley Eastern Ltd, 1980

Reference Books:

1. D. Montgomery, Statistical Quality Control: A Modern Introduction, John Wiley &Sons , 2009
2. I. Bazovsky, Reliability Theory and Practice, Prentice Hall Inc. Englewood Cliffs, New Jersey, 1961

COURSE INFORMATION SHEET

Course code: MA 401R1
Course title: Measure Theory and Integrations
Pre-requisite(s): Basics of real analysis, Riemann Integration.
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: VII / 4
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	Continuous functions and their bounded variation property
2.	Riemann Stieltjes Integration and their applications.
3.	Difference between Riemann Integration and Riemann Stieltjes Integration of functions.
4.	The concept of Lebesgue integration and their applications, different theorems and their applications.
5	Application of Fatou's lemma, Lebesgue dominated convergence theorem, Comparison of Lebesgue integral and Riemann integral.

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

CO1.	apply Riemann Stieltjes Integration on different boundary value problems
CO2.	apply Lebesgue theory and integration in the applications of qualitative theory of differential equations and difference equations.
CO3.	demonstrate a depth of understanding in advanced mathematical topics in relation to Biomathematics and engineering.
CO4	apply measure theory on functional analysis.
CO5	apply analysis on Topology.

Syllabus

MA401R1 Measure Theory and Integration 3-0-0-3

Module I

Properties of Monotone functions, Functions of bounded variation along with their properties, Total variation, Functions of bounded variation expressed as the difference of increasing functions, Continuous function of bounded variation. Jordan's rectifiable curve theorem. [8L]

Module II

Definition Riemann-Stieltjes integral, Linear properties, Change of variable in a Riemann-Stieltjes integral, Necessary and Sufficient conditions for existence of Riemann-Stieltjes integral, Mean value theorem for Riemann-Stieltjes integral. [8L]

Module III

Borel Sets, σ-ring, σ-algebra, Lebesgue outer measure, measurable sets and their properties, Lebesgue measure, measurable function. [8L]

Module IV

Simple function and measurable function, Lebesgue integral of a non-negative measurable function using simple functions, Lebesgue integral of functions of arbitrary sign and basic properties (linearity and monotonicity). [8L]

Module V

Monotone convergence theorem and its consequences, Fatou's lemma, Lebesgue dominated convergence theorem, Comparison of Lebesgue integral and Riemann integral. [8L]

Textbook:

1. H. L. Royden and P. M. Fitzpatrick – Real Analysis, Pearson, Fourth edition, 2017.

References:

1. R. R. Goldberg – Methods of Real Analysis, Oxford and IBH Publishing, 1970.
2. Tom M. Apostol – Mathematical Analysis, Second Edition, Addison Wesley, 1974.
3. Walter Rudin, Principles of Mathematical Analysis, McGraw Hill International Edition, 2014

COURSE INFORMATION SHEET

Course code: MA 402R1
Course title: ADVANCED COMPLEX ANALYSIS
Pre-requisite(s): MA110R1
Credits: L: 3 T:0 P: 0 C:0
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: VII / 4
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	properties of analytic complex variable functions
2.	convergence and divergence of sequence and series of complex variable functions, with special emphasis on Taylor and Laurent series
3.	theory behind multivalued functions associated with complex variables
4.	different properties associated with meromorphic functions
5.	convergence of infinite products of complex variable functions and their connection with zeros of entire functions

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

CO1	demonstrate the exclusive features related to derivatives and anti-derivatives of complex variable functions which forms the base of complex analysis
CO2	acquire the knowledge about the sequences and series of complex variable functions, their behaviors and connection with analytic functions
CO3	gain an understanding about multivalued complex variable functions and their properties
CO4	apply the knowledge of meromorphic functions in developing some special characteristics of complex variable transformations
CO5	utilize the conceptual understanding of entire functions to explore results related to their growth

SYLLABUS

MA402R1 ADVANCED COMPLEX ANALYSIS 3-0-0-3

Module I

Topology of the complex plane, Stereographic projection. Holomorphic (analytic) functions, Anti-derivatives, Cauchy-Goursat Theorem (simple and multiple connected domain), Cauchy – Integral Formula and its extensions, Cauchy's Inequality, Morera's theorem, Liouville's theorem. [8L]

Module II

Convergence of sequences and series, power series, absolute and uniform convergence of power series of complex functions, integration and differentiation of power series, radius of convergence, Taylor and Laurent series, analytic continuation. [8L]

Module III

Residues, Residue theorem. Multivalued functions and their properties, branch point, branch cut, evaluation of integrals involving branch point using calculus of residues. [8L]

Module IV

Meromorphic function and its properties, zeros and poles of meromorphic function, winding number, Argument principle, Rouche's theorem and its applications, Maximum Modulus theorem. [8L]

Module V

Infinite products, convergence of infinite products, Entire functions, Weierstrass primary factors, Weierstrass infinite product, Hadamard's factorization theorem, genus and order of entire function, growth of entire functions. [8L]

Textbooks:

1. E. M. Stein and R. Shakarchi, Complex Analysis, Princeton University Press, 2003.
2. J.B. Conway, Function of One Complex Variable, Springer – Verlag Publishers, Second Edition, 1978.
3. S. Ponnusamy and H. Silverman, Complex Variables with Applications, Birkhauser, 2006.
4. D. A. Wunsch. Complex Variables with Applications, Pearson Education, Third Edition, 2004.

Reference Books:

1. J.W. Brown and R.V. Churchill, Complex Variable and its Applications, Tata McGraw Hill Publications, 7th Edition, 2014.
2. H.S. Kasana, Complex Variables: Theory and Applications, PHI, Second Edition, 2005.
3. D.G. Zill and P.D. Shanahan, A First Course in Complex Analysis with Applications, Jones and Bartlett Publishers, 2003.

COURSE INFORMATION SHEET

Course code: MA404
Course title: Mathematical Epidemiology
Pre-requisite(s): Differential Equations
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 03 Lectures
Class: IMSc
Semester / Level: VII /4
Branch: Mathematics and Computing

Course Objectives: This course enables the students to

1.	understand the qualitative behaviour of linear and non-linear dynamical systems
2.	develop infectious disease deterministic and stochastic models
3.	formulate spatial epidemic models
4.	perform stability analysis of different types of epidemic models
5.	make predictions regarding the severity/non-severity of disease on basis of mathematical analysis.

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

CO1.	develop the skills to formulate the transmission dynamics that exists among different compartments
CO2.	demonstrate the basics of stability theory of differential equations in epidemiological models
CO3.	propose and analyses eco-epidemic models
CO4.	make predictions regarding the epidemic transmission and control
CO5.	demonstrate the applicability of mathematical modelling in simulating problems of epidemic

Syllabus

MA404 **Mathematical Epidemiology** **3-0-0-3**

Module I

Qualitative analysis of linear and nonlinear systems: Existence, uniqueness and continuity of solutions, Diagonalization of linear systems, fundamental theorem of linear systems, the phase paths of linear autonomous plane systems, complex eigenvalues, multiple eigenvalues, stability theorem, linearization of nonlinear dynamical systems (two, three and higher dimension), Stability: (i) asymptotic stability (Hartman's theorem), (ii) global stability (Lyapunov's second method). [8L]

Module II

Deterministic Epidemic Models: Deterministic model of simple epidemic, Infection through vertical and horizontal transmission, General epidemic- Kermack-Mckendrick Threshold Theorem, Recurrent epidemics, Seasonal variation in infection rate, allowance of incubation period, Simple model for the spatial spread of an epidemic. [8L]

Module III

Non-Constant Total Population Model in Epidemic: Introduction, Parasite-host system, SIS, SIR and SIRS type model. [8L]

Module IV

Stochastic Epidemic Models: Introduction, stochastic simple epidemic model, Yule-Furry model (pure birth process), expectation and variance of infective, calculation of expectation by using moment generating function. [8L]

Module V

Eco-Epidemiology: Introduction, host-parasite-predator systems, viral infection on phytoplankton zooplankton (prey-predator) system. [8L]

Textbooks:

1. Lawrence Perko, Differential Equations and Dynamical Systems, Springer, 2008.
2. N.T. J. Bailey, The Mathematical Theory of Infectious Diseases and its Application, London, Griffin, 1975.
3. J.D. Murray, Mathematical Biology, Springer and Verlag, 1990.
4. Vincenzo Capasso, Lecture Notes in Mathematical Biology (Vol. No. 97)- Mathematical Structures of Epidemic Systems, Springer Verlag, 1993.

Reference Books:

1. Busenberg and Cooke, Vertically Transmitted Diseases- Models and Dynamics, Springer Verlag, **1993**
2. Eric Renshaw, Modelling Biological Populations in Space and Time, Cambridge Univ. Press, 1990.

COURSE INFORMATION SHEET

Course code: MA 405
Course title: Mathematical Modelling
Pre-requisite(s): MA106R1, MA201R1, MA301R1, MA311R1
Credits: L:3 T:0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc
Semester/level: VII / 4
Branch: Mathematics and Computing

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-Event 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 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-Event 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]

Textbooks:

1. Frank R. Giordano, Mawrice D Weir, William P. Fox, A first course in Mathematical Modeling 3rd ed3 2003. Thomson Brooks/Cole.
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:

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

COURSE INFORMATION SHEET

Course code: MA406
Course title: Fuzzy Mathematical Programming
Pre-requisite(s): MA210
Credits: L: 3 T:0 P:0 C:3
Class schedule per week: 3 lectures
Class: IMSc
Semester: VII/ 4
Branch: Mathematics and Computing

Course Objectives:

1	Fuzzy Set Theory: Basic terminology and definition. Membership Function. Examples to generate membership functions.
2	Fuzzy Decision and Fuzzy Operators. Fuzzy Arithmetic: Addition, Subtraction, Multiplication and Division of Fuzzy Numbers, Triangular and Trapezoidal Fuzzy Numbers. Fuzzy Linear programming Models: Linear Programming Problem with Fuzzy Resources: Verdegay's Approach and 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's Chanas's and Verdegay's Approaches. Interactive Fuzzy Linear Programming - I. Problem Setting the Algorithm of IFLP-I.
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 mathematical programming.
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 Terminology and Definition. Support, α-level set, normality, convexity, Extension Principle, Compatibility of extension principle with α-cuts, relation, Decomposability, Decomposition Theorem. Basic Fuzzy operations: Complementation, Intersection, union, Algebraic Product, Algebraic Sum, Difference. Membership Function. A survey of various functional functions forms of membership functions. [8L]

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

MODULE III
Linear Programming with Fuzzy Resources and objective. Zimmermann's Approach. The Knox Production-Mix Selection Problem. Chana's Approach. An optimal system design Problem by Chanas approach. [8L]

MODULE IV
Linear Programming with Fuzzy parameters in the objective function. Linear Programming with all fuzzy coefficients. Interactive Fuzzy Linear Programming, Introduction, Interactive Fuzzy Linear Programming - I. Problem Setting. The Algorithm of IFLP-I. [8L]

MODULE V
Possibilistic Programming. Possibilistic Linear Programming models. Linear Programming with Imprecise Objective Coefficients by Lai and Hwang's Approach. Linear Programming with imprecise coefficients with Lai and Hwang’s Approach. [8L]

Textbooks:

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 INFORMATION SHEET

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

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.
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	Analyse 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; another 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]

Textbooks:

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 INFORMATION SHEET

Course code: MA 431

Course title: Applied Functional Analysis

Pre-requisite(s): Basics of Real Analysis and Linear Algebra

Credits: L: 3 T: 1 P: 0 C:4

Class schedule per week: 3 Lectures, 1 Tutorials

Class: IMSc

Semester / Level: VIII / 4

Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

1.	extension of concepts of Real analysis and Linear Algebra
2.	notions of Banach spaces and its applications.
3.	concepts of Bounded Linear operators on Hilbert spaces.
4.	extension of Eigen values and Eigen functions in Banach Spaces and Hilbert spaces.
5	applications of Spectral properties of various Bounded linear operators.

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

CO1.	understand the fundamental properties of Metric spaces.
CO2.	understand the theory of normed spaces, in particular Banach spaces and linear operators defined on them.
CO3	understand the concepts of inner product spaces, Hilbert spaces and their properties.
CO4.	understand the notions of Spectral theory extending the concepts of eigen value and eigen vectors.
CO5	apply the spectral properties of different linear operators on Hilbert spaces in Approximation theory.

Syllabus

MA431 — Applied Functional Analysis — 3-1-0-4

Module I Metric spaces:

Definition and examples. Holder's inequality, Minkowski's inequality, open sets, topological spaces, separable metric spaces, Cauchy sequence, complete metric space, Cantor's theorem, Baire's theorem, Compactness, Heine-Borel theorem, Continuity of functions, Banach fixed point Theorem. [9L]

Module II Normed Linear Spaces:

Normed Linear Spaces, Banach Spaces, Equivalent Norms, Finite dimensional normed linear spaces, Riesz Lemma. Bounded Linear Transformations, Normed linear spaces of bounded linear transformations, Uniform Boundedness Theorem, Open Mapping Theorem, Closed Graph Theorem, Linear Functionals, Hahn-Banach Theorem, Dual Space, and Reflexivity of Banach Spaces**.** [9L]

Module III Inner Product Spaces:

Inner Product Space**,** Cauchy-Schwarz Inequality, Parallelogram law, Pythagorean Theorem, Hilbert Spaces, Orthonormal Sets, Complete Orthonormal Sets, Legendre Polynomials, Hermite Polynomials, Orthogonal Complement and Direct Sums, Projection operators, Riesz Representation Theorem. [9L]

Module IV Spectral Theory:

Basic Concepts, Eigen Values, Eigen Vectors, Existence theorem, Spectrum, Resolvent set, Spectrum Theorem, Spectral radius. Invertibility, Spectral mapping theorem for polynomials. [9L]

Module V Operators and further Applications:

Hilbert Adjoint operator, Self-Adjoint, Unitary and Normal operators. Compact operators and their spectral properties, Fredholm Alternatives. Ascoli Theorem. Applications of Hilbert and Banach spaces and operators to Differential, Integral Equations and Approximation theory. [9L]

Textbooks:

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

Reference Books:

1. Erwin Kreyszig, Introductory functional analysis wit 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 INFORMATION SHEET

Course code: MA 502
Course title: Number Theory
Pre-requisite(s): Modern Algebra, Linear Algebra
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, 1 Tutorials
Class: IMSc.
Semester / Level: VIII / 4
Branch: Mathematics and Computing

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

CO1	apply the number theory to specific research problems in mathematics or in other fields.
CO2	Use Fermat's, Euler's and Chinese remainder theorems to solve congruence equations arise in various research problems
CO3	solve Pell's equation with the use of continued fraction, and learn how to find primitive roots
CO4	use Primality test and factorization algorithm to factor large composite numbers.
CO5	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]

Textbooks

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 INFORMATION SHEET

Course code: MA 413
Course title: Stochastic Process and Simulation
Pre-requisite(s): Basics of statistics and probability
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 lectures.
Class: IMSc
Semester / Level: VIII / 4
Branch: Mathematics and Computing

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

1.	Generating functions, Laplace Transforms and their applications
2.	Stochastic process and their classifications
3.	Markov chain and its applications
4.	Poisson process, its postulates and applications; also, renewal and diffusion process, Brownian motion
5.	Simulate various probability distributions both discrete and continuous

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

CO1.	apply the concept of concept of generating functions and Laplace transforms in real life problems
CO2.	classify a stochastic process given a real-life situation
CO3.	apply Markov chain in real life problems
CO4.	apply Poisson other appropriate stochastic process in real life problems
CO5.	generate variates from discrete and continuous probability distributions and use them in simulation studies

Syllabus

MA413 Stochastic Process and Simulation 3-0-0-3

Module I

Generating Function and probability generating function with applications, Laplace transforms (LT), properties and applications of Laplace transforms, Laplace transforms for a random variable. **[8L]**

Module II

Definition of a stochastic process, classification of a stochastic process, applications in queues, birth and death processes, concept of stationarity, Gaussian process. **[8L]**

Module III

Markov chains, order of a Markov chain, classifications of chains and states, applications of Markov chains, Random walk, martingales, gambler's ruin problem. **[8L]**

Module IV

Poisson Process and its postulates, properties and applications, Renewal process, Diffusion process and Brownian motion. **[8L]**

Module V

Simulation: definition, Monte Carlo Simulation, techniques for simulating well known discrete and continuous probability distributions (Binomial, Poisson, discrete uniform, Geometric, Hypergeometric, Negative Binomial, continuous uniform, Normal, exponential, Chi-Square, Cauchy, t, F, Beta 1, Beta 2). **[8L]**

Textbooks:

1. J. Medhi, Stochastic Processes, New Age International Publishers
2. S. M. Ross, Simulation, Academic Press

Reference Books:

1. S. Karlin and H. M. Taylor, A First Course in Stochastic Processes Academic Press, N.Y.
2. U.N. Bhat and G. K. Miller, Elements of Applied Stochastic Processes, Wiley

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.**
Semester/level: **VIII/4**
Branch: **Mathematics and Computing**/ Mathematics

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]

Textbooks:

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 INFORMATION SHEET

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

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	analyse the motion and shape of orbits in planetary motion.
CO3	determine the solution of isoperimetric and brachistochrone's problems.
CO4	analyse 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]

Textbooks:

1. Ray M., A textbook 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 INFORMATION SHEET

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

Course Objectives: This course enables the students to

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

Textbooks:

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 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
Class: IMSc
Semester/Level: VIII/4
Branch: Mathematics and Computing

Course Objectives:

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. [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. The first method for constructing the additive value function. [8L]

Module V

Domination structures and non-dominated solutions. Introduction, Domination structures. Constant dominated cone structures. A characterization of n points and their polars. General properties of N-points. Cone convexity and N-points. N points in decision space. [8L]

Textbooks:

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 Books:

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 INFORMATION SHEET

Course code: MA524
Course title: Advanced Mathematical Techniques
Pre-requisite(s): Ordinary and Partial Differential equations, Numerical Techniques
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: VIII/4
Branch: Mathematics and Computing/ Mathematics

Course Objectives: This course enables the students to understand the

1.	qualitative behaviour of linear and non-linear dynamical systems
2.	integral equation, its classification, different types of kernels.
3.	different types of solution methods like successive approximation, resolvent kernel, iteration method, integral transform method and which method is applicable for whichtype of integral equation.
4.	numerical issues such as the stability, condition of convergence and the compatibilityof the methods that have been introduced to find the numerical solutions of partial differential equation (s) of specific type. 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	demonstrate the basics of stability theory of dynamical systems.
CO2	acquire sound knowledge of different types of Integral equations: Fredholm and Volterra integral equations etc.
CO3	obtain integral equation from ODE and PDE arising in applied mathematics anddifferent engineering branches and solve accordingly using various method of solving integral equation.
CO4	approximate the partial differential equations using appropriate finite differencescheme and analyses the consistency, stability and convergence properties of such numerical methods.
CO5	enhance and develop the ability of using the language of mathematics in analysing the real-world problems of sciences and engineering.

Syllabus

MA524 **Advanced Mathematical Techniques** **3-0-0-3**

Module I

Introduction to dynamical systems, Linear Systems, Solution of homogeneous and non-homogeneous systems, Fundamental Matrix, Autonomous system and stability, linearization of nonlinear dynamical systems, Lyapunov's method. [8L]

Module II

Definition, classification of integral equation, types of kernels. Conversion of IVPs into Volterra integral equation, BVPs into Fredholm integral equation. Solution of Fredholm integral equations with separable (degenerate) kernels. [8L]

Module III

Method of successive approximation: Iterated kernels, Resolvent kernel, solution of Fredholm and Volterra equation of second kind by successive substitutions (method of iteration). Symmetric kernel, orthonormal system of function, fundamental properties of eigenvalues and Eigen functions for symmetric kernels. [8L]

Module IV

Numerical Partial Differential Equations: Finite difference approximations to partial derivatives, solution of Laplace & Poisson's equations using standard five pt. formula & diagonal five pt. formula. [8L]

Module V

Solution of one - dimensional heat conduction equation, FTCS, BTCS and Crank Nicolson method. Solutionof wave equation, Upwind method and Lax- Wendroff method. Consistency, stability and convergence of finite difference methods. [8L]

Textbooks:

1. Perko and Lawrence, Differential Equations and Dynamical Systems, Texts in Applied Mathematics,2001.
2. David Porter, David S.G. Stirling: Integral Equation, Cambridge Texts in Applied Mathematics.
3. Pradip Niyogi, Introduction to Computational Fluid Dynamics, Pearson Education India, 2006.
4. J.W. Thomas, Numerical Partial Differential Equations: Finite Difference Methods, Springer, 1995.

Reference Book:

1. M.D. Raisinghania: Integral Equations and Boundary Value Problems, 2016.
2. William E. Boyce & Richard C. Diprima, Elementary Differential Equations and Boundary ValueProblems, 9ed Paperback, 2009.

COURSE INFORMATION SHEET

Course code: MA 414R1
Course title: Advanced Operations Research
Pre-requisite(s): Optimization Techniques, Introductory probability and statistics, linear
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures, 0 Tutorial
Class: IMSc
Semester / Level: IX / 5
Branch: Mathematics and Computing

Course Objectives: This course enables the students to:

1.	Understand theoretical knowledge of Dynamic Programming and flexibility to solve a multi-stage decision problem with recursive equations.
2.	Familiarize with inventory management and its functional role in different organizations. Handle various inventory models under a mathematical framework and develop skills in managing inventories optimally.
3.	Make decision under various decision making environments like certainty and risk ; and determine strategies to win a game
4.	Identify and examine situations that generate queuing problems. Identify the optimal balance between the cost of service and the cost of the waiting line. Analyze a variety of performance measures of a queuing system
5	To understand the fundamentals of optimization techniques of nonlinear functions for both constrained and unconstrained problems.

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

CO 1	Conceptualize various dynamic programming models and their application in solving multi-stage decision problems.
CO 2	Determine optimal economic order quantity (EOQ) for minimizing total inventory cost and handle various inventory problems of deterministic types.
CO 3	Make appropriate decisions and determine strategies to win a game.
CO 4	Analyze various performance measures of queuing systems, and derive those performance measures for single server and multiple server queuing models.
CO 5	Differentiate between nonlinear unconstrained and constrained optimization problems with equality and inequality constraints and solve them with appropriate techniques.

Syllabus

MA414R1 — Advanced Operation Research — 3-0-0-3

Module I

Dynamic Programming: Introduction of Dynamic Programming, Deterministic Dynamic Programming: Forward and Backward Recursion, Applications of Dynamic Programming on Cargo load problem and inventory Models, Solution of linear programming problems by dynamic programming. [8L]

Module II

Inventory Management: Introduction to general inventory Models, Classical Economic Order Quantity (EOQ) models, Inventory models with multiple price breaks, EOQ with price breaks(One and two Price breaks only), multi-item EOQ with storage limitations. Introduction to dynamic EOQ Models, Introduction to Stochastic inventory models. [8L]

Module III

Decision Analysis and Games: Decision making under certainty, risk and uncertainty. Optimal Solution of Two-Person Zero-Sum games and solution of mixed strategy games.[8L]

Module IV

Queuing Theory: Basic elements of queuing models, Pure Birth and Death Models, Poisson Queuing systems: single server models- {(M/M/1):(∞/FCFS)}, {(M/M/1):(N/FCFS)}, multiple server models-{(M/M/S):(∞/FCFS)}, {(M/M/S):(N/FCFS)}. [8L]

Module V

Classical Optimization Theory and Non-linear Programming: Unconstrained optimization: Fibonacci and Golden section method, Gradient Method: Steepest descent, conjugate direction methods and Newton's method. Constraint Optimization with equality constraints: Lagrange's Multiplier Method, Constraint Optimization with inequality constraints: Kuhn Tucker Conditions, Quadratic Programming. [8L]

Textbooks:

1. Hamdy A Taha: Operations Research, Pearson Education.
2. Kanti Swarup, P.K.Gupta and Manmohan: Operations Research, Sultan chand & Sons.
3. S. S. Rao: Engineering Optimization: Theory and Practice, Fourth Edition,John Wiley and Sons.

Reference Books:

1. Hiller and Lieberman: Operation Research, McGraw Hill.
2. J. K. Sharma: Operations Research: Theory and applications, Mac-Millan Publishers.

COURSE INFORMATION SHEET

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

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** **3-0-0-3**

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 INFORMATION SHEET

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

Course Objectives: This course enables the students to understand the

1.	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** **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's minimum principle and state inequality constraints, Hamilton-Jacobi-Bellman equation. [8L]

Module V

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

Textbooks:

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 INFORMATION SHEET

Course code: MA 506R1

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

Semester / Level: IX / 5

Branch: Mathematics and Computing

Name of Teacher:

Course Objectives: This course enables the students to understand the

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	differentiate 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 506R1 **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. The Logistic equation: Introduction, The two-cycle, higher cycles. Physical systems: Modeling and time scales, Law of cooling, Biological Sciences: Single-species Population models, 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. [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. [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 [8L]

Textbooks:

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 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
Semester/level: IX/5
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

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

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

CO1	learn the background and get an introduction for the use of numerical methods to solve partial differential equations.
CO2	apply the concepts of finite difference and finite volume methods to solve the fluid mechanics problem and other real word problems
CO3	analyse the consistency, stability and convergence analysis of numerical schemes.
CO4	choose appropriate numerical methods to solve the fluid flow problem.
CO5	understand the limitation of numerical methods and various techniques 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]**

Textbooks:

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.

COURSE INFORMATION SHEET

Course code: MA 510
Course title: Advanced Differential Equations
Pre-requisite(s): ordinary and partial differential equations
Credits: L: 3 T: 0 P:0 C:3
Class schedule per week: 3 lectures.
Class: IMSc
Semester / Level: IX / 5
Branch: Mathematics and Computing

Course Objectives: This course enables the students to understand the

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 Advanced Differential Equations 3-0-0-3

Module I

Existence and uniqueness of solution of initial value problems for first order ODEs, singular solutions offirst order ODEs, system of first order ODEs . Introduction, definition of stability, linear systems, almostlinear 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]**

Textbooks:

1. 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 PublishingHouse
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 INFORMATION SHEET

Course code: MA 523
Course title: Computational Mathematics
Pre-requisite(s):
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 3 Lectures
Class: IMSc
Semester / Level: IX/5
Branch: Mathematics and Computing

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

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. Vibratingmembrane. [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 onedimensional problem. Application to two dimensional problems. [8L]

Test Books:

1. Advanced Engineering Mathematics – E. Kreyszig
2. Linear Partial Differential Equations for Scientists and Engineers, Lokenath Debnathand 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 variationalMethods 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 INFORMATION SHEET

Course code: MA 412R1
Course title: Topology
Pre-requisite(s): Basics of real Analysis and Functional Analysis
Co- requisite(s): ---
Credits: L: 3 T: 0 P: 0 C:3
Class schedule per week: 03 Lectures, 0 Tutorial
Class: IMSc/ MSc
Semester / Level: XI/5
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand the

1.	concept of a Topological space which generalizes the spaces arising in Real and Functional Analysis
2.	generalization of the concept of continuity on Topological spaces
3.	connectedness and compactness of spaces through the concepts of topological properties.
4	generalization of different structure of spaces to Topological spaces
5	fundamental concepts of topology.

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

CO1.	understand the concept of topology in real world problems.
CO2.	applications of topological approach in the study of solutions of different boundary value problems using differential equations arising in Biological and Ecological systems and different engineering problems.
CO3.	applications of topological approach to study the qualitative properties of solutions of mathematical models arising in real world phenomena.
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

MA412R1 **Topology** 3-0-0-3

Module I

Topological spaces: Definition and examples, Basis for a Topology, Standard Topology, Sub-basis. Product Topology: Definition, Projections, Subspace Topology, Closed sets and Limit points: closure and interior of a set, Hausdorff space, Continuity of a function on Topological Space, Homeomorphisms, Rules for constructing continuous functions. [8L]

Module II

Metric Topology: Metrizable space, Euclidean metric, uniform topology, Subspaces, Uniform convergence of sequence of functions, Uniform limit theorem, Quotient Topology: Quotient map, Quotient space. example and glimpse of continuous maps on quotient spaces in specific situations.

Connected spaces: Separation and connected space, union of connected sets, continuous image of connected spaces, Cartesian product of connected spaces, Path connected spaces: Definition and examples, Components and path components, local connectedness. [8L]

Module - III

Countability and Separation Axioms: Countable basis, first and second countable axioms, dense sets, separable space, Separable axioms: Housdroff space, Regular space, Normal Space, completely regular space, Urishon's lemma, Tietze Extension theorem. [8L]

Module- IV

Compact Spaces: Cover, Open cover, Compactness: basic results and finite Intersection property, Compact subspaces of real line, Extreme value theorem, the Lebesgue number lemma, uniformly continuous, uniform continuity theorem, Limit points and Compactness, sequentially compact, local compactness and one point compactification. [8L]

Module V

Compactness in Metric Spaces: ε-net, Lebesgue number, equivalence of compactness, sequential compactness and limit point compactness in a metric space, uniform continuity theorem. [8L]

Textbook:

1. J. R. Munkres – Topology, Pearson New International Edition, 2^{nd} Edition, 2013.

Reference Books:

1. W. J. Thron – Topological Structures.
2. K. D. Joshi – Introduction to General Topology.
3. J. L. Kelly – General Topology.
4. G. F. Simmons – Introduction to Topology & Modern Analysis.

COURSE INFORMATION SHEET

Course code: MA 318

Course title: Artificial Neural Network

Pre-requisite(s): Matrix operations (some linear algebra), some multivariate calculus and basic probability theory, mathematical optimization, partial derivatives, linear regression to logistic regression.

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

Class schedule per week: 3 Lectures

Class: IMSc

Semester / Level: V/ 3

Branch: Mathematics and Computing

Course objectives: In this course the students will be introduced to

1.	various neural network models and algorithms, adaptive behavior, associative learning, competitive dynamics and biological mechanisms.
2.	understand the structure, design, and training of various types of neural networks
3.	apply them to the solution of problems in a variety of domains.

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

CO1.	describe fundamental concepts of biological and artificial neurons.
CO2.	describe functional aspects of single layer perceptron and multi-layer perceptron
CO3.	use various ANN learning algorithms in real life problems.
CO4.	understand various associative memory network models for pattern recognition, time-series analysis.
CO5.	describe functionalities of RBF and SOM network

Syllabus

MA318 **Artificial Neural Network** **3-0-0-3**

Module I

Introduction of Neural Networks and Human Brain, Biological and Artificial Neuron, Models of a Neuron, Different types of Activation functions, Perceptron Model, Adaline Model, Neural Networks viewed as Directed Graphs, Network Architectures, characteristics of Neural Networks. [8L]

Module II

Learning Processes: Error-Correction Learning, Memory–Based Learning, Hebbian Learning, Competitive learning, Boltzmann Learning, learning with a teacher (supervised), Learning without a teacher (unsupervised). Learning Tasks: Pattern Association, Pattern Recognition and Function Association. [8L]

Module III

Single Layer Perceptron: Introduction, Unconstrained Optimization Techniques: Method of Steepest Descent, Newton's Method, Gauss Newton Method, Least Mean Square Algorithm. Perceptron, Perceptron Convergence Theorem (Statement only). Multiple Layer Perceptron: Back-Propagation Algorithm, XOR Problem. ART1: Architecture of ART1, Special Features of ART1 Models and ART1 Algorithm, ART2: Architecture of ART2, ART2 Algorithm. [8L]

Module IV

Bidirectional Associative Memory (BAM), Radial Basis Function Networks: Cover's theorem on the separability of patterns, Separating Capacity of a surface, Interpolation Problem, Micchelli's theorem. Neurodynamical Models: Additive Model, Hopfield Model, Relation between the Stable States of the Discrete and Continuous versions of the Hopfield Model. The Discrete Hopfield Model as a Content-Addressable Memory. Brain –State-In-A-Box Model, Lyapunov Function of the BSB Model, Dynamics of the BSB model. [8L]

Module V

Principal Component Analysis: Introduction, Some intuitive Principles of Self-Organization, Principal Component Analysis. Self-Organizing Maps: Introduction, Two Basic Feature-Mapping Models, Self-Organizing Map, Properties of the Feature Map. [8L]

Textbooks:

1. Haykin Simon, Neural network, Addison Wesley Longman Pvt. Ltd, Delhi.

Reference Book:

1. Jacek M. Zurada, Introduction to Artificial Neural Systems, Jaico Publishing House.
2. Rajasekaran and Pai G.A. V. Neural Networks, Fuzzy logic and Genetic Algorithm, Prentice Hall of India.
3. Laurence Faucett, Fundamentals of Neural Networks, Architectures, Algorithms and Applications.