BIRLA INSTITUTE OF TECHNOLOGY- MESRA, RANCHI
NEWCOURSE STRUCTURE - To be effective from academic session 2018- 19
Based on CBCS system & OBE model
Recommended scheme of study
(*For Integrated MSc. in Mathematics and Computing*)

UG Program (1st - 6th Semester)

Semester/ Session of Study (Recommended)	Level	Category of course	Course Code	Subjects	Mode of delivery & credits *L-Lecture; T-Tutorial; P-Practicals*			Total Credits *C-Credits*
					L (*Periods/week*)	T (*Periods/ week*)	P (*Periods/ week*)	C (*Credits*)
FIRST Monsoon	THEORY							
	1	PC Program Core	MA101	Calculus-I	3	1	0	4
			MA102	Real Analysis	3	1	0	4
			MA109	Matrix Theory	3	1	0	4
		HSS *Humanities & Social Sciences*	MT123	Business Communications	2	0	2	3
		FS Foundation Sciences	CH111	Chemistry –I	3	1	0	4
	LABORATORIES							
	1	FS	CH112	Chemistry –I Lab	0	0	3	1.5
		MC Mandatory Course	MC 101/102/ 103/104	Choice of : NCC/NSS/ PT & Games / Creative Arts (CA)	0	0	2	1
TOTAL								21.5
SECOND Spring	THEORY							
	1	PC	MA105	Calculus-II	3	1	0	4
			MA106	Ordinary Differential Equations	3	1	0	4
			MA110	Complex Analysis	3	1	0	4

		FS	CE101	Environmental Science	2	0	0	2
			PH109	Physics I	3	1	0	4
		GE General Engineering	CS101	Programming for problem solving	3	1	0	4
	LABORATORIES							
	1	**FS**	PH110	Physics I Lab	0	0	3	1.5
		GE	CS102	Programming for problem solving	0	0	3	1.5
		MC	MC 105/106/ 107/108	Choice of : NCC/NSS/ PT & Games / Creative Arts (CA)	0	0	2	1
TOTAL								**26**
GRAND TOTAL FOR FIRST YEAR								**47.5**
THIRD Monsoon	**THEORY**							
	2	**PC**	MA201	Partial Differential Equations	3	1	0	4
			MA202	Modern Algebra	3	1	0	4
			MA208	Integral Transforms and its Applications	3	1	0	4
			CS201	Data Structure	3	1	0	4
	1	**FS**	PH111	Physics –II	3	1	0	4
	LABORATORIES							
	2	**PC**	CS202	Data Structure Lab	0	0	3	1.5
	1	**FS**	PH112	Physics –II Lab	0	0	3	1.5
	2	**MC**	MC 201/202/ 203/204	Choice of : NCC/NSS/ PT & Games/ Creative Arts CA)	0	0	2	1
TOTAL								**24**

	THEORY

FOURTH Spring	**2**	**PC**	MA205	Discrete Mathematics	3	1	0	4
			MA206	Linear Algebra	3	1	0	4
			MA209	Integral Equations and Green's Function	3	1	0	4
			CS204	Object Oriented Programming and Design Pattern	3	0	0	3
		FS	CH213	Chemistry II	3	1	0	4
	LABORATORIES							
	2	**PC**	CS205	Object Oriented Programming and Design Pattern Lab	0	0	3	1.5
		FS	CH214	Chemistry II Lab	0	0	3	1.5
		MC	MC 205/206/ 207/208	Choice of : NCC/NSS/ PT & Games/ Creative Arts (CA)	0	0	2	1
TOTAL								**23**
FIFTH Monsoon	**THEORY**							
	3	**PC**	MA301	Probability and Statistics	3	1	0	4
			MA303	Fuzzy Logic	3	1	0	4
	2		CS 206	Design and Analysis of Algorithm	3	0	0	3
	3		CS 310	Formal Languages & Automata Theory	3	0	0	3
	3	**PE* Program Electives**	Dept Codes	PE I^{A} (Maths)	3	1	0	4
			Dept Codes	PE II^{B} (Maths/CSE)	3	0	0	3
	LABORATORIES							
	3	**PC**	MA 302	Probability and Statistics Lab	0	0	3	1.5
	2		CS 207	Design and Analysis of Algorithm Lab	0	0	3	1.5
TOTAL								**24**

SIXTH Spring	**THEORY**							
	3	**PC**	MA309	Optimization Techniques	3	1	0	4

			MA311	Numerical Techniques	3	1	0	4
			CS 301	Database Management System	3	0	0	3
			CS 303	Operating Systems	3	0	0	3
		PE*	Dept Codes	PE III[C] (Maths)	3	1	0	4
			Dept Codes	PE IV[D] (Maths/CSE)	3	0	0	3
	LABORATORIES							
	3	**PC**	MA 310	Optimization Techniques Lab	0	0	3	1.5
			MA 312	Numerical Techniques Lab	0	0	3	1.5
			CS 302	Database Management System Lab.	0	0	3	1.5
TOTAL								**25.5**

***Course Code and Course Name of Program Electives will depend on the choice of the subjects from that group.**	
Internship (In-house/External) of at least 2 months should be done by the students (Non-credit) during 5th/6th semester.	
Minimum requirement for Degree award of B.Sc. Honours in Mathematics and Computing (1st - 6th Semester)	**144**

PG Program (7th - 10th Semester)								
Semester/ Session of Study (Recommended)	**Level**	**Category of course**	**Course Code**	**Subjects**	**Mode of delivery & credits L-Lecture; T- Tutorial; P-Practicals**			**Total Credits *C-Credits***
					L (Periods/week)	**T (Periods /week)**	**P (Periods /week)**	**C**

SEVENTH Monsoon	**THEORY**							
	4	**PC**	MA 401	Real Analysis and Measure Theory	3	1	0	4
			MA 402	Advanced Complex Analysis	3	1	0	4
	6		CA603	System Simulation and Modeling	3	0	0	3
	5		CA505	Software Engineering	3	1	0	4
	5	**PE***	**Dept Codes**	**PE** V[E] (Maths)	3	0	0	3
			Dept Codes	**PE** VI[F] (Maths / CSE)	3	0	0	3
		OE* Open Electives		**OE-I**	3	0	0	3
	LABORATORIES							
	5	**PC**	CA506	Software Engineering Lab	0	0	3	1.5
TOTAL								**25.5**
EIGHTH Spring	**THEORY**							
	4	**PC**	MA412	Topology	3	1	0	4
			MA413	Stochastic Processes and Simulation	3	0	0	3
			MA414	Advanced Operation Research	3	1	0	4
	4		CA559	Data Communication and Computer Networks	3	1	0	4
	4	**PE***	**Dept Codes**	**PE** VII[G] (Maths / CSE)	3	0	0	3
		OE*		**OE-II**	3	0	0	3
	LABORATORIES							
	4	**PC**	MA415	Advanced Operation Research Lab.	**0**	**0**	**3**	**1.5**
	5	**PC**	CA560	Data Communication and Computer Networks Lab.	**0**	**0**	**3**	**1.5**
TOTAL								**24.0**
NINTH Monsoon		**THEORY**						
	5	**PC**	MA501	Functional Analysis	3	1	0	4

			MA502	Number Theory	3	1	0	4
	6		CA601	Computer Graphics	3	0	0	3
	5	**PE***	Dept Codes	**PE** VIII^{H} (Maths / CSE)	3	0	0	3
			Dept Codes	**PE** IX^{I} (Maths / CSE)	3	0	0	3
	LABORATORIES							
	6		**CA602**	Computer Graphics Lab	0	0	3	1.5
	2	**MC**	**MT204**	Constitution of India	2	0	0	0
TOTAL								**18.5**
TENTH Spring	**5**	**RP Research Project / Industry Internship**	**MA509**	**Research Project / Industry Internship**	**0**	**0**	**0**	**12**
Total								**12**
Total credits of Integrated M.Sc. in Mathematics and Computing (7th - 10th Semester)								**80**
Minimum requirement for Degree award of Integrated M. Sc. in Mathematics and Computing (1st - 10th Semester)								**224**

DEPARTMENT OF MATHEMATICS PROGRAMME ELECTIVES: PE OFFERED FOR SEMESTER 5-9/ Level 3-5								
PE / LEVEL		**Prerequisites Subjects with code**	**Code no.**	**Name of the PE subjects**	**L**	**T**	**P**	**C**
PE I^{A} V Sem.	**3**	MA106, MA201	MA304	Tensor Analysis	3	1	0	4
		MA205	MA305	Graph Theory	3	1	0	4
		MA105	MA306	Special Functions	3	1	0	4
PE II^{B} V Sem.	**3**	MA106, MA201	MA307	Computational Linear Algebra	3	0	0	3

		MA106, MA201	MA308	Difference Equations	3	0	0	3
			CS391	Introduction to Distributed System	3	0	0	3
		MA205	CS321	Soft Computing	3	0	0	3
PE III^{C} VI Sem.	**3**	MA205	MA313	Combinatorics	3	1	0	4
		MA303	MA314	Fuzzy Set Theory and its applications	3	1	0	4
		MA301	MA315	Financial Mathematics	3	1	0	4
		MA301	MA316	Statistics Quality Control and Reliability	3	1	0	4
PE III^{D} VI Sem.	**3**	MA106	MA317	Wavelet Transform	3	0	0	3
		MA102, MA105	MA318	Artificial Neural Network	3	0	0	3
			IT322	Cloud Computing	3	0	0	3
		CS301	CS325	Database Modelling	3	0	0	3
		NIL	CS324	Systems Programming				
PE V^{E} VII Sem.	**4**	MA106, MA201	MA404	Mathematical Epidemiology	3	0	0	3
		MA106, MA201	MA405	Mathematical Modelling	3	0	0	3
		MA205	MA406	Fuzzy Mathematical Programming	3	0	0	3
		MA301	MA407	Survey Sampling	3	0	0	3

PE VI^{F} VII Sem.	**4**	MA106, MA201	MA408	Theory of Elasticity	3	0	0	3
		MA301, MA407	MA409	Design of Experiments	3	0	0	3
		MA105	MA410	Differential Geometry	3	0	0	3
	5		CA532	Data Mining and Warehousing	3	0	0	3
PE VII^{G} VIII Sem.	**4**	MA301	MA416	Statistical Inference	3	0	0	3
		MA106, MA201	MA418	Mechanics	3	0	0	3
		MA106, MA201	MA419	Mathematical Ecology	3	0	0	3

		MA309, MA414	MA427	Multiple-Criteria Decision Making	3	0	0	3
	5		CA584	Web Programming	3	0	0	3
	6	CS206	CA640	Machine Learning	3	0	0	3
PE VIII^H IX Sem.	**5**	MA301	MA503	Statistical Computing	3	0	0	3
		MA106, MA201	MA504	Finite Element Methods	3	0	0	3
		MA106, MA201, MA309	MA505	Calculus of Variations and Optimal Control	3	0	0	3
		MA106, MA201	MA506	Advanced Difference Equations	3	0	0	3
PE IX^I IX Sem.	**5**	MA106, MA201	MA507	Computational Fluid Dynamics	3	0	0	3
		MA106, MA201	MA508	Qualitative Theory of Differential Equations	3	0	0	3
	6		CA630	Cryptography & Network Security	3	1	0	4
			CA635	Natural Language Processing	3	0	0	3

BIRLA INSTITUTE OF TECHNOLOGY- MESRA, RANCHI
NEW COURSE STRUCTURE - To be effective from academic session 2018- 19
Based on CBCS system & OBE model
Recommended scheme of study

Details of credits distribution for IMSc. in Mathematics and Computing (category wise)

UG Program (1st - 6th Semester)

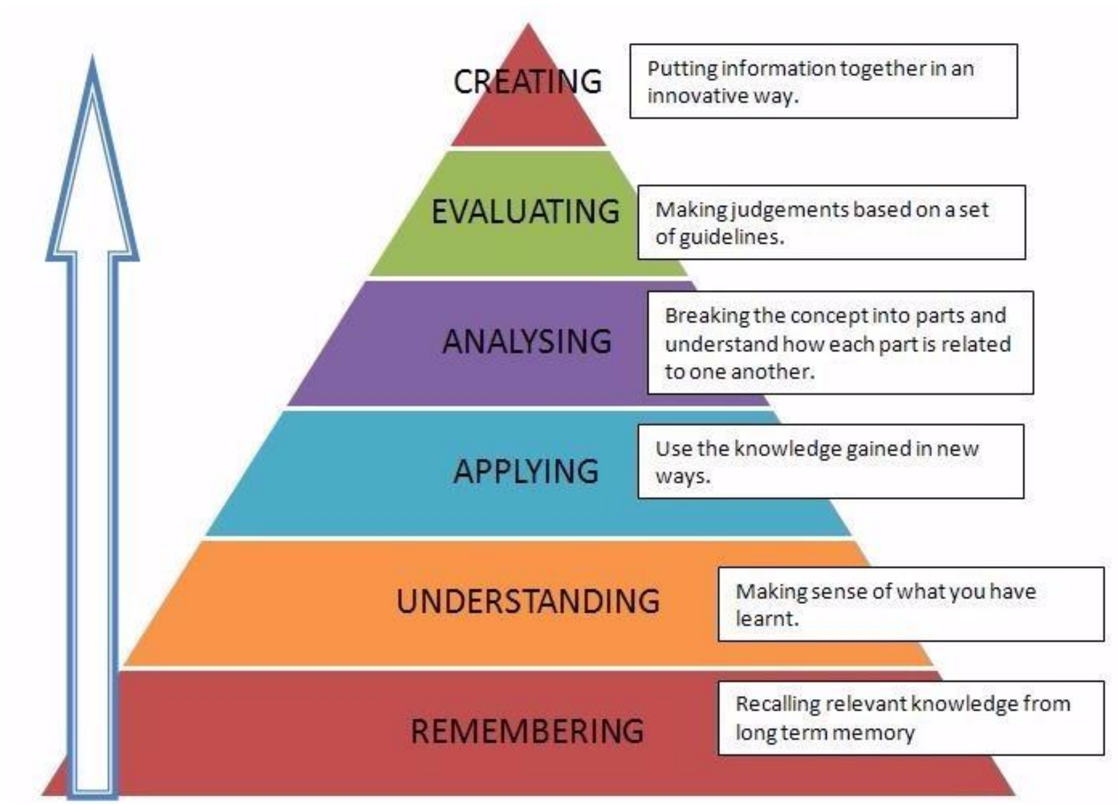
S. No	**Category**	**Credits**
1	**PC**-Program Core (Mathematics & Computer Science)	68.5+25 = 93.5
2	**HSS**-Humanities & Social Sciences	3
3	**FS**-Foundation Science	24
4	**GE**-General Engineering	5.5
5	**PE**-Program Electives (Mathematics & Computer Science)	14
6	**MC**- Mandatory Course: NCC/NSS/Creative Arts/ PT & Games	4
	TOTAL	144

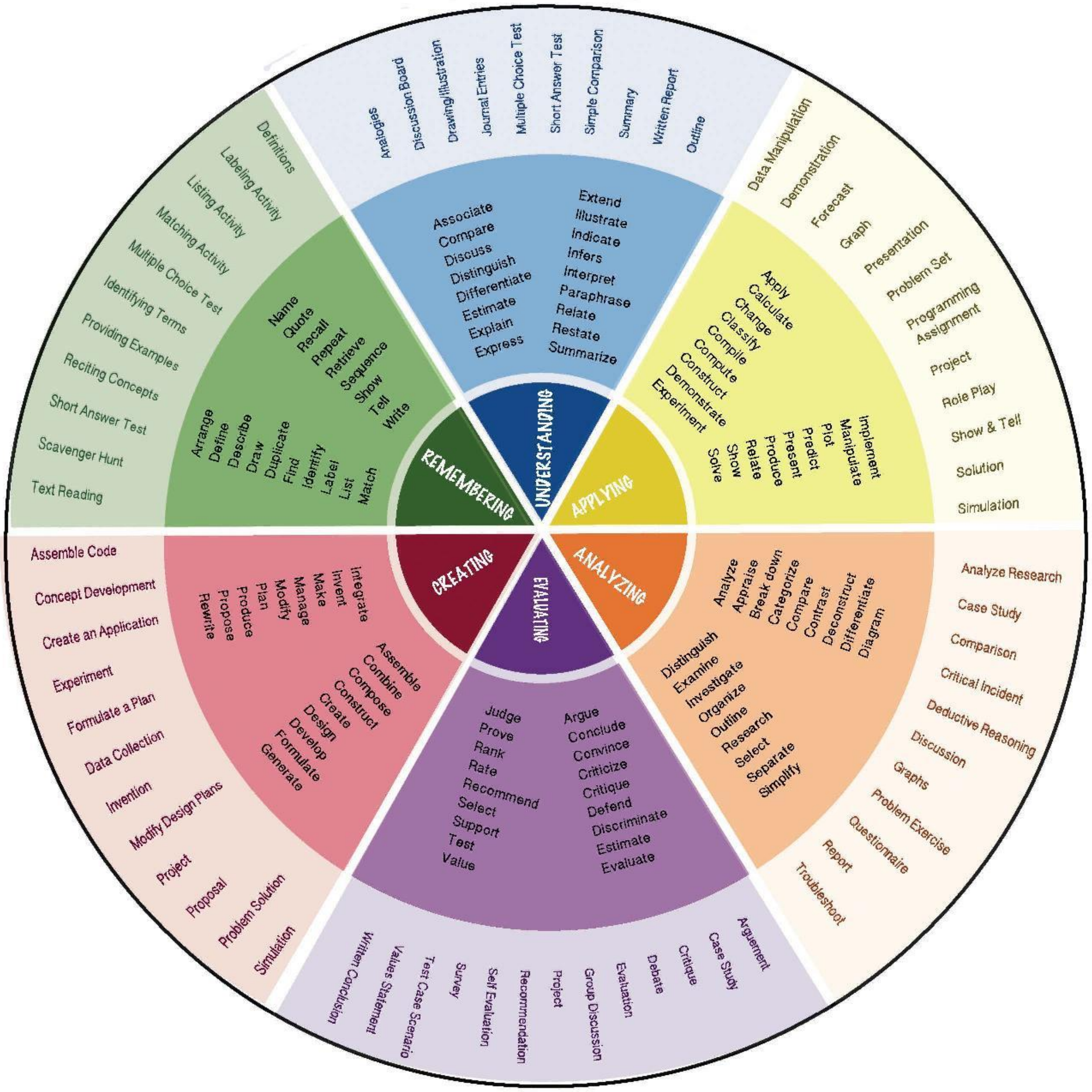
PG Program (7th - 10th Semester)			
S. No	**Category**		**Credits**
1	**PC**-Program Core (Mathematics & Computer Science)		28.5+18.5=47
2	**PE**-Program Electives (Mathematics & Computer Science)		15
3	**OE**-Open Electives		6
4	**Research Projects**		12
5	**MC- Mandatory Course (Constitution of India)**		0
TOTAL			80
Program total Credits for IMSc. in Mathematics and Computing: **144(UG)+80(PG) = 224 Credits**			

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.


CREATING
Putting information together in an innovative way.
EVALUATING
Making judgements based on a set of guidelines.
ANALYSING
Breaking the concept into parts and understand how each part is related to one another.
APPLYING
Use the knowledge gained in new ways.
UNDERSTANDING
Making sense of what you have learnt.
REMEMBERING
Recalling relevant knowledge from long term memory


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

CHOICE BASED CREDIT SYSTEM (CBCS) CURRICULUM

(Effective from Academic Session: Monsoon 2018)

PROGRAMME

5 Years Integrated Master of Science in Mathematics and Computing

Department of Mathematics

Institute Vision

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

Institute Mission

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

Department Vision

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

Department Mission

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

CBCS based Syllabus for IMSc in Mathematics and Computing
(1st - 10th Semester)

Important notes:

- The basic criteria of UGC have been followed in preparing the course structure of this programme.
- The Exit option with B.Sc. Honours in Mathematics and Computing can be offered to them who want to get it after successful completion of 6th semester.
- Otherwise IMSc in Mathematics and Computing would be offered to them after the successful completion of 10th semester.

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 Team Work**: 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 in order to effectively communicate design, analysis and research results.

9 be able to acquire competent positions in industry and academia as well.

10 be able to acquire lifelong learning and continuous professional development.

11 be conscious of financial aspects of all professional activities and shall be able to undertake projects with appropriate management control and control on cost and time.

12 recognize the need for continuous learning and will prepare himself/ herself appropriately for his/her all-round development throughout the professional career.

(B) Programme Specific Outcomes (PSOs)

13. 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.
14. Demonstrate combined knowledge of mathematics and computing to manage projects efficiently and economically with intellectual integrity and ethics for sustainable development of society.
15. Capable of using his/her knowledge of mathematical sciences in higher studies of interdisciplinary nature.

BIRLA INSTITUTE OF TECHNOLOGY- MESRA, RANCHI
NEWCOURSE STRUCTURE - To be effective from academic session 2018- 19
Based on CBCS system & OBE model
Recommended scheme of study
(*For Integrated MSc. in Mathematics and Computing*)

UG Program (1st - 6th Semester)								
Semester/ Session of Study (Recommended)	**Level**	**Category of course**	**Course Code**	**Subjects**	**Mode of delivery & credits** *L-Lecture; T-Tutorial; P-Practicals*			**Total Credits** *C-Credits*
					L (*Periods /week*)	**T *(Periods/ week)***	**P *(Periods/ week)***	**C (*Credits*)**
FIRST Monsoon	**THEORY**							
	1	**PC Program Core**	MA101	Calculus-I	3	1	0	4
			MA102	Real Analysis	3	1	0	4
			MA109	Matrix Theory	3	1	0	4
		HSS *Humanities & Social Sciences*	MT123	Business Communications	2	0	2	3
		FS Foundation Sciences	CH111	Chemistry –I	3	1	0	4
	LABORATORIES							
	1	**FS**	CH112	Chemistry –I Lab	0	0	3	1.5
		MC Mandatory Course	MC 101/102/ 103/104	Choice of : NCC/NSS/ PT & Games / Creative Arts (CA)	0	0	2	1
TOTAL								**21.5**
SECOND Spring	**THEORY**							
	1	**PC**	MA105	Calculus-II	3	1	0	4
			MA106	Ordinary Differential Equations	3	1	0	4
			MA110	Complex Analysis	3	1	0	4

		FS	CE101	Environmental Science	2	0	0	2
			PH109	Physics I	3	1	0	4
		GE General Engineering	CS101	Programming for problem solving	3	1	0	4
	LABORATORIES							
	1	**FS**	PH110	Physics I Lab	0	0	3	1.5
		GE	CS102	Programming for problem solving	0	0	3	1.5
		MC	MC 105/106/ 107/108	Choice of : NCC/NSS/ PT & Games / Creative Arts (CA)	0	0	2	1
TOTAL								**26**
GRAND TOTAL FOR FIRST YEAR								**47.5**
THIRD Monsoon	**THEORY**							
	2	**PC**	MA201	Partial Differential Equations	3	1	0	4
			MA202	Modern Algebra	3	1	0	4
			MA208	Integral Transforms and its Applications	3	1	0	4
			CS201	Data Structure	3	1	0	4
	1	**FS**	PH111	Physics –II	3	1	0	4
	LABORATORIES							
	2	**PC**	CS202	Data Structure Lab	0	0	3	1.5
	1	**FS**	PH112	Physics –II Lab	0	0	3	1.5
	2	**MC**	MC 201/202/ 203/204	Choice of : NCC/NSS/ PT & Games/ Creative Arts CA)	0	0	2	1
TOTAL								**24**

FOURTH Spring	THEORY							
	2	PC	MA205	Discrete Mathematics	3	1	0	4
			MA206	Linear Algebra	3	1	0	4
			MA209	Integral Equations and Green's Function	3	1	0	4
			CS204	Object Oriented Programming and Design Pattern	3	0	0	3
		FS	CH213	Chemistry II	3	1	0	4
	LABORATORIES							
	2	PC	CS205	Object Oriented Programming and Design Pattern Lab	0	0	3	1.5
		FS	CH214	Chemistry II Lab	0	0	3	1.5
		MC	MC 205/206/ 207/208	Choice of : NCC/NSS/ PT & Games/ Creative Arts (CA)	0	0	2	1
TOTAL								23
FIFTH Monsoon	THEORY							
	3	PC	MA301	Probability and Statistics	3	1	0	4
			MA303	Fuzzy Logic	3	1	0	4
	2		CS 206	Design and Analysis of Algorithm	3	0	0	3
	3		CS 310	Formal Languages & Automata Theory	3	0	0	3
	3	PE* Program Electives	Dept Codes	PE I[A] (Maths)	3	1	0	4
			Dept Codes	PE II[B] (Maths/CSE)	3	0	0	3
	LABORATORIES							
	3	PC	MA 302	Probability and Statistics Lab	0	0	3	1.5
	2		CS 207	Design and Analysis of Algorithm Lab	0	0	3	1.5
TOTAL								24

SIXTH Spring	**THEORY**							
	3	**PC**	MA309	Optimization Techniques	3	1	0	4
			MA311	Numerical Techniques	3	1	0	4
			CS 301	Database Management System	3	0	0	3
			CS 303	Operating Systems	3	0	0	3
		PE*	Dept Codes	PE III[C] (Maths)	3	1	0	4
			Dept Codes	PE IV[D] (Maths/CSE)	3	0	0	3
	LABORATORIES							
	3	**PC**	MA 310	Optimization Techniques Lab	0	0	3	1.5
			MA 312	Numerical Techniques Lab	0	0	3	1.5
			CS 302	Database Management System Lab.	0	0	3	1.5
TOTAL								**25.5**

***Course Code and Course Name of Program Electives will depend on the choice of the subjects from that group.**	
Internship (In-house/External) of at least 2 months should be done by the students (Non-credit) during 5th/6th semester.	
Minimum requirement for Degree award of B.Sc. Honours in Mathematics and Computing (1st - 6th Semester)	**144**

PG Program (7th - 10th Semester)								
Semester/ Session of Study (Recommended)	**Level**	**Category of course**	**Course Code**	**Subjects**	**Mode of delivery & credits L-Lecture; T- Tutorial; P-Practicals**			**Total Credits *C-Credits***
					L (Periods/week)	**T (Periods /week)**	**P (Periods /week)**	**C**
SEVENTH Monsoon	**THEORY**							
	4	**PC**	MA 401	Real Analysis and Measure Theory	3	1	0	4
			MA 402	Advanced Complex Analysis	3	1	0	4
	6		CA603	System Simulation and Modeling	3	0	0	3
	5		CA505	Software Engineering	3	1	0	4
	5	**PE***	**Dept Codes**	**PE** V[E] (Maths)	3	0	0	3
			Dept Codes	**PE** VI[F] (Maths / CSE)	3	0	0	3
		OE* Open Electives		**OE-I**	3	0	0	3
	LABORATORIES							
	5	**PC**	CA506	Software Engineering Lab	0	0	3	1.5
TOTAL								**25.5**
EIGHTH Spring	**THEORY**							
	4	**PC**	MA412	Topology	3	1	0	4
			MA413	Stochastic Processes and Simulation	3	0	0	3
			MA414	Advanced Operation Research	3	1	0	4
	4		CA559	Data Communication and Computer Networks	3	1	0	4
	4	**PE***	**Dept Codes**	**PE** VII[G] (Maths / CSE)	3	0	0	3
		OE*		**OE-II**	3	0	0	3

	LABORATORIES							
	4	**PC**	MA415	Advanced Operation Research Lab.	**0**	**0**	**3**	**1.5**
	5	**PC**	CA560	Data Communication and Computer Networks Lab.	**0**	**0**	**3**	**1.5**
TOTAL								**24.0**
NINTH Monsoon		**THEORY**						
	5	**PC**	MA501	Functional Analysis	3	1	0	4
			MA502	Number Theory	3	1	0	4
	6		CA601	Computer Graphics	3	0	0	3
	5	**PE***	Dept Codes	**PE** VIII[H] (Maths / CSE)	3	0	0	3
			Dept Codes	**PE** IX[I] (Maths / CSE)	3	0	0	3
	LABORATORIES							
	6		**CA602**	Computer Graphics Lab	0	0	3	1.5
	2	**MC**	**MT204**	Constitution of India	2	0	0	0
TOTAL								**18.5**
TENTH Spring	**5**	**RP Research Project / Industry Internship**	**MA509**	**Research Project / Industry Internship**	**0**	**0**	**0**	**12**
Total								**12**
Total credits of Integrated M.Sc. in Mathematics and Computing (7th - 10th Semester)								**80**
Minimum requirement for Degree award of Integrated M. Sc. in Mathematics and Computing (1st - 10th Semester)								**224**

DEPARTMENT OF MATHEMATICS PROGRAMME ELECTIVES: PE OFFERED FOR SEMESTER 5-9/ Level 3-5								
PE / LEVEL		**Prerequisites Subjects with code**	**Code no.**	**Name of the PE subjects**	**L**	**T**	**P**	**C**
PE I[A] V Sem.	**3**	MA106, MA201	MA304	Tensor Analysis	3	1	0	4
		MA205	MA305	Graph Theory	3	1	0	4
		MA105	MA306	Special Functions	3	1	0	4
PE II[B] V Sem.	**3**	MA106, MA201	MA307	Computational Linear Algebra	3	0	0	3
		MA106, MA201	MA308	Difference Equations	3	0	0	3
			CS391	Introduction to Distributed System	3	0	0	3
		MA205	CS321	Soft Computing	3	0	0	3
PE III[C] VI Sem.	**3**	MA205	MA313	Combinatorics	3	1	0	4
		MA303	MA314	Fuzzy Set Theory and its applications	3	1	0	4
		MA301	MA315	Financial Mathematics	3	1	0	4
		MA301	MA316	Statistics Quality Control and Reliability	3	1	0	4
PE III[D] VI Sem.	**3**	MA106	MA317	Wavelet Transform	3	0	0	3
		MA102, MA105	MA318	Artificial Neural Network	3	0	0	3
			IT322	Cloud Computing	3	0	0	3
		CS301	CS325	Database Modelling	3	0	0	3
		NIL	CS324	Systems Programming				
PE V[E] VII Sem.	**4**	MA106, MA201	MA404	Mathematical Epidemiology	3	0	0	3
		MA106, MA201	MA405	Mathematical Modelling	3	0	0	3
		MA205	MA406	Fuzzy Mathematical Programming	3	0	0	3
		MA301	MA407	Survey Sampling	3	0	0	3

PE VI[F] VII Sem.	**4**	MA106, MA201	MA408	Theory of Elasticity	3	0	0	3
		MA301, MA407	MA409	Design of Experiments	3	0	0	3
		MA105	MA410	Differential Geometry	3	0	0	3
	5		CA532	Data Mining and Warehousing	3	0	0	3
PE VII[G] VIII Sem.	**4**	MA301	MA416	Statistical Inference	3	0	0	3
		MA106, MA201	MA418	Mechanics	3	0	0	3
		MA106, MA201	MA419	Mathematical Ecology	3	0	0	3
		MA309, MA414	MA427	Multiple-Criteria Decision Making	3	0	0	3
	5		CA584	Web Programming	3	0	0	3
	6	CS206	CA640	Machine Learning	3	0	0	3
PE VIII[H] IX Sem.	**5**	MA301	MA503	Statistical Computing	3	0	0	3
		MA106, MA201	MA504	Finite Element Methods	3	0	0	3
		MA106, MA201, MA309	MA505	Calculus of Variations and Optimal Control	3	0	0	3
		MA106, MA201	MA506	Advanced Difference Equations	3	0	0	3
PE IX[I] IX Sem.	**5**	MA106, MA201	MA507	Computational Fluid Dynamics	3	0	0	3
		MA106, MA201	MA508	Qualitative Theory of Differential Equations	3	0	0	3
	6		CA630	Cryptography & Network Security	3	1	0	4
			CA635	Natural Language Processing	3	0	0	3

BIRLA INSTITUTE OF TECHNOLOGY- MESRA, RANCHI
NEW COURSE STRUCTURE - To be effective from academic session 2018- 19
Based on CBCS system & OBE model
Recommended scheme of study

Details of credits distribution for IMSc. in Mathematics and Computing (category wise)

UG Program (1st - 6th Semester)

S. No	**Category**	**Credits**
1	**PC**-Program Core (Mathematics & Computer Science)	68.5+25 = 93.5
2	**HSS**-Humanities & Social Sciences	3
3	**FS**-Foundation Science	24
4	**GE**-General Engineering	5.5
5	**PE**-Program Electives (Mathematics & Computer Science)	14
6	**MC**- Mandatory Course: NCC/NSS/Creative Arts/ PT & Games	4
	TOTAL	144

PG Program (7th - 10th Semester)

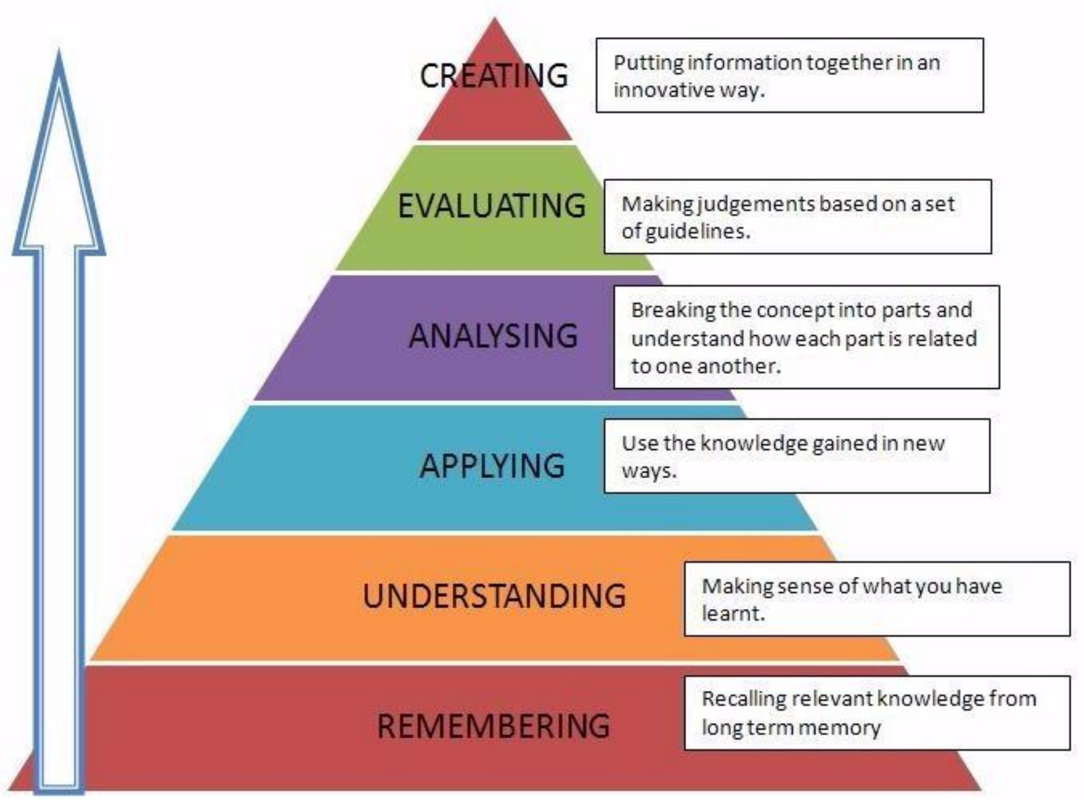
S. No	**Category**	**Credits**
1	**PC**-Program Core (Mathematics & Computer Science)	28.5+18.5=47
2	**PE**-Program Electives (Mathematics & Computer Science)	15
3	**OE**-Open Electives	6
4	**Research Projects**	12
5	**MC- Mandatory Course (Constitution of India)**	0
	TOTAL	80

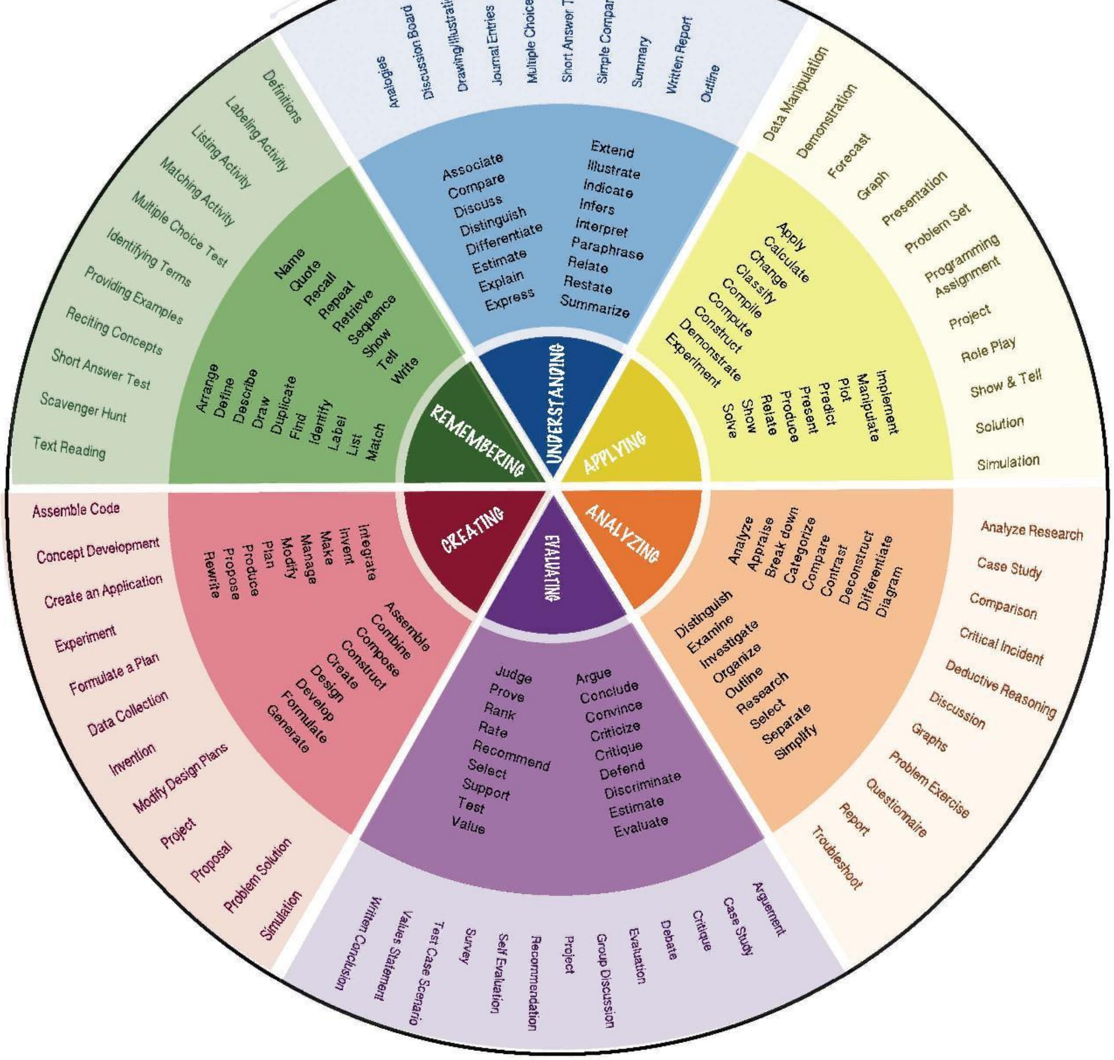
Program total Credits for IMSc. in Mathematics and Computing:
144(UG)+80(PG) = 224 Credits

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
UNDERSTANDING
APPLYING
ANALYZING
EVALUATING
CREATING
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
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
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
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
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
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

Details Syllabi for Choice Based Credit System of IMSC

in
Mathematics and Computing

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
Name of the Faculty:
Course Objectives: This course enables the students to understand the

1.	behaviour 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 behaviour 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]

Text Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Making students solve engineering problems using the studied concepts.
2. Experimentally visualising the analytical concepts.
3. Difficult to produce extensive proves of the state-of-the-art definitions and theorems.

POs met through Gaps in the Syllabus

3, 4, 12

Topics beyond syllabus/Advanced topics/Design

1. Proofs of the said theorems
2. For students to come up with innovative ideas and carry out project works during the running semester is beyond syllabus
3. Industrial visits to train them of the challenges in the industry and support students to do Projects at industries

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 12

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	3	3	3	3	3	1	1	1	1	1	1	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD7, CD 8
CO2	CD1 and CD9
CO3	CD1, CD2 and CD3
CO4	CD1 and CD2
CO5	CD1 and CD2

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
Name of the Faculty:

Course Objectives: This course enables the students to understand

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.

Syllabus

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]

Text Books:

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.
2. S. K. Mapa, Introduction to Real Analysis (Revised 6th edition), Sarat book distributers, 2011.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design
1. All fixed point theorems related to Functional Analysis

POs met through Topics beyond syllabus/Advanced topics/Design
2, 3

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

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

Indirect Assessment –
1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

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
Name of the faculty:

Course objectives: This course enables the students to understand

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.	apply the matrix theory to study other branches of mathematics like algebra, vector analysis, cryptography, graph theory etc.
CO2.	apply the matrix theory to analyze the quantitative and qualitative properties of solutions of mathematical models in biological, ecological systems and in engineering problems.
CO3.	apply the matrix theory to study the properties of solutions of different algebraic systems.
CO4.	apply the matrix theory in different problems of computer graphics, electrical engineering, civil engineering, robotics and automation.
CO5.	apply the matrix theory in recording data arising in geology for seismic survey.

Syllabus

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]

Text books:

1. S. Lipschutz, M. L. Lipson: Schaum's Outline of Linear Algebra, Mcgraw-Hill.
2. David c. Lay, Linear Algebra and its Applications (3rd Edition), Pearson Ed. Asia, Indian Reprint, 2007.

Reference book:

1. Higher Algebra Abstract and Linear, S K Mapa, Levant Publications.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Solving the large size system of linear equation
2. Numerical technique for solving the system of linear equations.

POs met through Gaps in the Syllabus

4

Topics beyond syllabus/Advanced topics/Design

1. Jordan Canonical Form
2. Inner product space
3. Gram-Schimdt Orthogonalisation Process

POs met through Topics beyond syllabus/Advanced topics/Design

4

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome.

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)											Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA105
Course title: Calculus-II
Pre-requisite(s): Calculus-I
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 lectures, 1 tutorial
Class: IMSc.
Semester/level: II/1
Branch: Mathematics and Computing
Name of the Faculty:

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

1.	coordinate axes and 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 plane and surfaces in 3-dimensional space.
CO2.	visualize and deal with problems consisting of surface area, volume of solids and derive different important quantities as Centre of Mass and Moments.
CO3.	explain the characteristics of scalar and vector valued functions and 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 of using the language of mathematics in analyzing the real-world problems of sciences and engineering.

Syllabus

MA105 **Calculus-II** **3-1-0-4**

Module I

Three-dimensional space: rectangular coordinates in 3D space, parametric equations of lines, planes, sphere and cylinder. [9L]

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, Center of Mass and Moment of Inertia. [9L]

Module III

Vector valued functions, unit tangent, normal and binormal vectors, curvature, torsion and TNB frame.

Motion along the curves: Tangential and normal components of velocity and acceleration.

Calculus of scalar and vector point functions, Gradient, Directional derivative, Divergence and curl, properties, second order derivatives, identities. [9L]

Module IV

Line integrals, vector field, work, circulation, path independence, potential function and conservative field.

Surface integral, flux, volume integral, Gauss, Green's and Stoke's theorems, application of vector calculus in engineering problems. [9L]

Module V

Transformation of coordinates, orthogonal curvilinear coordinates, Gradient, divergence and curl in curvilinear co-ordinate systems, Special orthogonal curvilinear coordinate system: cylindrical, spherical, etc. [9L]

Text Books:

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, 11th edition, Pearson Educations, 2008.
3. H Anton, I Brivens, S. Davis: Calculus, 10th Edition, John Wiley and sons, Singapore Pte. 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.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Application of fluid dynamics

POs met through Gaps in the Syllabus

3, 12

Topics beyond syllabus/Advanced topics/Design

1. fluid dynamics

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 12

<u>Course outcome (co) attainment assessment tools & evaluation procedure</u>

<u>Direct assessment</u>

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 106
Course title: Ordinary Differential Equations
Pre-requisite(s): Differentiation, Integration.
Credits: L: 3 T: 1 P:0 C:4
Class schedule per week: 3 lectures, 1 tutorial
Class: IMSc
Semester / Level: II/1
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

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, series solution. Bessel's and Legendre's equations
4.	Initial value problems, stability, Adjoint differential equations, Sturm-Liouville problem, Fourier series.

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

CO1	identify, analyse 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 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

MA106 **Ordinary Differential Equations** **3-1-0-4**

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). [10L]

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. [10L]

Module III

Simultaneous linear differential equations with constant coefficients, total differential equation and condition of integrability. [7L]

Module IV

Series solution around an ordinary point and a regular singular point, the method of Frobenius. Bessel and Legendre equations. [9L]

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. [9L]

Text Books:

1. G.F. Simmons: Differential Equations with Applications and Historical Notes, McGraw-Hill
2. R. C. DiPrima and W. E. Boyce: Ordinary Differential Equations and Boundary Value Problems, Willey
3. Dennis G. Zill, Warren S. Wright: Advanced Engineering Mathematics, Jones and Bartlett Pubs.
4. Edwards & Penney: Differential Equations and Boundary value problems, Pearson Education
5. S. L. Ross: Differential Equations, Wiley

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. V. Sundarapandian: Ordinary and Partial Differential Equations, McGraw-Hill

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Application of ordinary differential equations

POs met through Gaps in the Syllabus

3,4,12

Topics beyond syllabus/Advanced topics/Design

1. Advanced differential equation
2. Partial differential equation

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 12

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 110
Course title: Complex Analysis
Pre-requisite(s): Complex Numbers, Basic Calculus
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C: 4
Class schedule per week: 3 lectures, 1 tutorial.
Class: IMSc
Semester / Level: II/I
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

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, which are not the features of their real analogues
CO2.	develop an understanding to prove the analytical results related to theory of complex variable functions
CO3.	conceptualise the differentiation and integration of complex variable functions
CO4.	acquire the skills to evaluate complicated real variable function properties in the light of complex variable theory
CO5.	apply the knowledge of complex variable theory in diverse fields related to mathematics

Syllabus

MA110 **Complex Analysis** **3-1-0-4**

Module I

Complex Differentiation: Regions in the complex plane, function of a complex variable, Limit, continuity, differentiability and analyticity of complex variable functions, analytic functions, Cauchy – Riemann equations in cartesian and polar forms, harmonic functions, harmonic conjugates, Milne Thomson method [9 L]

Module II

Complex Integration: Integration of complex variable function along contour**,** line integral, properties of line integrals, Cauchy's theorem, Cauchy's Integral Formula, Cauchy's Integral formula for derivatives of analytic function, Cauchy's Inequality. [9 L]

Module III

Infinite Series and Singularities: Power Series, convergence of power series, Taylor's series, Laurent Series.

Zeros and singularities of analytic function, types of singularities, properties of singular points [9L]

Module IV

Calculus of Residues: Residues, computation of residues at pole, Cauchy – Residue theorem. Application of residue calculus in evaluation of improper real integrals of types $\int_0^{2\pi} f(\cos\theta, \sin\theta)\,d\theta$ and $\int_{-\infty}^{\infty} f(x)\,dx$ [9L]

Module V

Conformal Mapping: Mapping (or Transformation) of complex variable function, Conformal Mapping, Types of elementary transformations – translation, rotation, magnification, inversion, Bilinear transformation, properties of bilinear transformation. [9L]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Applications of complex variable theory in different real - life situations

POs met through Gaps in the Syllabus

2, 3, 9

Topics beyond syllabus/Advanced topics/Design:

1. Evaluation of complicated real integrals using complex variable technique

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√	√	
End semester examination	√	√	√	√	
Quiz (s)		√	√		
Assignment	√	√	√	√	√

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2
CO4	CD2, CD3
CO5	CD3, CD8

COURSE INFORMATION SHEET

Course code: MA 201
Course title: Partial Differential Equation
Pre-requisite(s): Differentiation, Integration.
Co- requisite(s): ---
Credits: L: 3 T: 1 P:0 C:4
Class schedule per week: 3 lectures, 1 tutorial.
Class: IMSc
Semester / Level: III/2
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

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, analyse 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

MA201 **Partial Differential Equation** **3-1-0-4**

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. [10L]

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. [10L]

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). [9L]

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]

Text Books

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Application of Transient Heat Conduction Analysis.
2. Application of PDE for steady-state Heat Conduction Analysis.
3. Application of Transverse Vibration of Cable Structure.

POs met through Gaps in the Syllabus

3, 4, 12

Topics beyond syllabus/Advanced topics/Design

1. Monge's Method.
2. Three dimensional Wave and Laplace Equation by Separation Variable.
3. Non-linear One-dimensional Wave Equations.

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD7, CD 8
CO2	CD1 and CD9
CO3	CD1, CD2 and CD3
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 202
Course title: Modern Algebra
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 3 T: 1 P:0 C:4
Class schedule per week: 3 lectures, I tutorial.
Class: IMSc.
Semester / Level: III/2
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	Basics of set, relation, mapping, equivalence relation and partition, residue class of integers, Chinese remainder theorem, partition of integer, primitive roots.
2.	binary operation, group, permutation groups, 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.

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

CO1.	understand relation, partition of groups, permutation and direct product of groups, conjugacy classes, solvable group, finitely generated abelian group, rings, subring, integral domains etc.
CO2.	effectively write abstract mathematical proofs in a clear and logical manner and apply the theory of abstract algebra to specific research problems in mathematics or other fields.
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.	gain an understanding to solve problems with the use of abstract algebra to diverse situations in mathematical contexts.
CO5.	locate and use theorems to solve problems in number theory, use of ring theory to cryptography

Syllabus

MA202 **Modern Algebra** **3-1-0-4**

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, Mobius inversion formula. [9L]

Module II

Binary operations, introduction to groups (Symmetric group, Quaternion group, Dihedral group), permutation groups, subgroups, cyclic groups, cosets and Lagrange's theorem, normal subgroup, quotient groups, simple group. homomorphism's and isomorphism's of groups, Cayley's theorem, correspondence theorem and its corollary, direct products of groups. [9L]

Module III

Conjugacy classes, Cauchy's theorem and p-groups, Sylow's theorems and application. Finitely generated Abelian groups, fundamental theorem of finitely generated abelian group, invariant factors, elementary divisors. [9L]

Module IV

Introduction to rings, integral domain 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. [9L]

Module V

Polynomial Rings, division Algorithm of R[x], where R is commutative ring with unity. Divisibility in Integral Domains, prime and irreducible elements. Concept and results about PID, ED and UFD. Reducibility tests, irreducibility test, UFD in Z[x]). [9L]

Text Books:

1. J.B. Fralieigh: A first Course in Abstract Algebra, Addison-Wesley
2. Joseph A.Gallian: Contemporary Abstract Algebra, Narosa Publishing House
3. I. N. Herstein: Topics in Algebra, Wiley
4. M. Artin: Algebra, Prentice Hall of India

Reference Books:

1. S.K. Mapa: Higher Algebra (Linear and Modern), Levant Publisher
2. V. K. Khanna & S.K. Bhambri: A Course in Abstract Algebra, Vikas Publishing House
3. A.K. Vasishtha & A.R. Vasishtha: Modern Algebra, Krishna Prakashan Media
4. Surjeet Singh & Qazi Zameeruddin: Modern Algebra, Vikas Publishing House

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Linear Algebra

POs met through Gaps in the Syllabus

3,4,12

Topics beyond syllabus/Advanced topics/Design

1. Galois Theory
2. Field Extension
3. Vector space

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4,

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 208
Course title: Integral Transform and Applications
Pre-requisite(s): Some background in Ordinary and partial differential
Co- requisite(s): ---
Credits: L: 3 T: 1 P:0 C:4
Class schedule per week: 03 Lectures, 1 Tutorial
Class: IMSc.
Semester / Level: III/ 2
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	the 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.	the 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

MA208 — Integral Transform and Applications — 3-1-0-4

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. [9L]

Module II

Laplace Transform**:** 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) and integral equations. [10L]

Module III

Fourier Transform: 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). [10L]

Module IV

Henkel Transform: 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

Z-Transform: 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, solution of difference equations using z -Transform. [8L]

Text Books:

1. I.N Sneddon: The use of integral Transforms, McGraw-Hill
2. K. Sankara Rao: Introduction to Partial Differential Equations, PHI Learning
3. B. V. Ramana: Higher Engineering Mathematics, McGraw Hill
4. R.K Jain, S.R.K Iyengar: Advanced Engineering Mathematics, Narosa Publication
5. R.S. Pathak: The wavelet Transform, Atlantis Press

References:

1. M.D. Raisinghania: Advanced Differential Equations, S. Chand & Co
2. Vasishtha & Gupta: Integral Transforms, Krishna Prakashan, Meerut

Gaps in the Syllabus (to meet Industry/Profession requirements):

1. Problems related to Social and environmental issues are not addressed.
2. Mellin Transform.
3. Application of Mellin Transform in Speech Recognition
4. Application of The Mellin Transformation in solving fuchsian type partial differential equations

POs met through Gaps in the Syllabus

5, 10, 11, 12

Topics beyond syllabus/Advanced topics/Design:

1. Solution of Integral equations using Laplace transforms.
2. Solution of difference equations using z -Transform.

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	2	2	3	3	3	1	1	1	3	2	3
CO2	3	2	2	2	2	2	3	3	3	1	1	1	3	2	3
CO3	3	3	2	2	2	2	3	3	3	1	1	1	3	2	3
CO4	2	2	3	1	2	2	3	3	3	1	1	1	3	2	3
CO5	2	2	2	2	2	2	3	3	3	1	1	1	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 and CD8
CO2	CD1, CD2 and CD8
CO3	CD1, CD2 and CD8
CO4	CD1, CD2 and CD8
CO5	CD2, CD3 and CD4

COURSE INFORMATION SHEET

Course code: MA 205
Course title: Discrete Mathematics
Pre-requisite(s):
Co- requisite(s):
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 Lectures, 1 tutorial
Class: IMSc
Semester / Level: IV/2
Branch: Mathematics and Computing
Name of Teacher:

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.	able to solve set theoretic and generating function problems
CO3.	apply mathematical logic and reasoning to solve real time problems
CO4.	be familiar with algebraic systems, groups, subgroups and Lagrange’s theorem
CO5.	understand the concepts in graph theory and would able to apply in real world problems

Syllabus

MA 205 **Discrete Mathematics** **3-1-0-4**

Module I

Mathematical logic and Mathematical Reasoning, Compound Statements, Propositional Equivalences, Predicates and Quantifiers, Methods of Proof, Mathematical Induction, Well-ordering principal, Recursive Definition and Algorithms. [9L]

Module II

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

Set, Operations on Set, Computer representation of Set, Relations, Properties/Classification of Relations, Closure operations on Relations, Matrix representation of Relations, Digraphs. Functions and their Representation, Classification of Functions, Warshall's algorithm, Discrete Numeric Functions, Growth of Functions, Big O , Big Θ , Hash Function, Growth Functions. [9L]

Module IV

Binary Operations, Groups, Product and Quotients of Groups, Semi group, Products and Quotients of Semi groups, Permutation Group, Composition of Permutation, Inverse Permutation, Cyclic Permutation, Transposition, Even and Odd Permutation, Coding of Binary Information and Error Correction, Decoding and Error Correction. [9L]

Module V

Introduction to Graph, Graph Terminologies and their Representation, Connected & Disconnected graphs, Isomorphic Graph, Euler & Hamilton graphs. Introduction to Trees, Versatility of Trees, Tree traversal. Spanning Trees, Minimum Spanning Tree. [9L]

Text Books:

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.

Reference Books:

1. Bikash Kanti Sarkar and Swapan Kumar Chakraborty, *Combinatorics and Graph Theory*, PHI, 2016.
2. Seymour Lipschuz and Mark Lipson, *Discrete Mathematics*, Shaum’s outlines, 2003.
3. Liu, Chung Laung, *Elements of Discrete mathematis*, Mcgraw Hill, 2nd edition, 2001.
4. Bondy and Murty, Grapg Theory with Applications, American Elsevier,1979.
5. Robin J. Wilson, Introduction to Graph Theory, Pearson, 2010.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Permutations and combinations
2. Relation between group theory and coding of binary information
3. Connectivity concept in graphs.

POs met through Gaps in the Syllabus

3, 4, 10

Topics beyond syllabus/Advanced topics/Design

1. Boolean algebra and lattices
2. Counting the number of sub groups in a finite group
3. Planar graphs and graph coloring

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 10, 12

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD 8
CO2	CD1, CD8
CO3	CD1, CD2 and CD3
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 206
Course title: Linear Algebra
Pre-requisite(s):
Co- requisite(s): ---
Credits: L:3 T: 1 P: 0 C:4
Class schedule per week: 3 lectures, 1 tutorial
Class: IMSc.
Semester / Level: IV/2
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	the basic ideas of vector algebra, linear dependent and independent set, basis
2.	the fundamental properties of eigenvalue, eigenvectors of a linear transformation
3.	Various types of real quadratic forms and their applications
4.	be familiar with the notion of inner product space and orthogonal vectors

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.	find the eigenvalues and eigenvectors of a square matrix and to know diagonalizable matrix
CO3.	handle a non-diagonalizable matrix with the help of upper triangular form or Jordan canonical form
CO4.	understand the concept of positive and negative definite of matrices arising problems in optimization and engineering
CO5.	apply linear algebra to solve initial and boundary value problems for ordinary differential equations

Syllabus

MA206 **Linear Algebra** **3-1-0-4**

Module I

Vector spaces, subspaces, linear combination, linear span, spanning sets, linearly dependence and independence, Basis and dimension of a vector space, sums. [9L]

Module II

Linear transformation (L.T.), kernel and image, rank-nullity theorem and its applications, singular and non-singular L.T, matrix representation of a linear transformation, change-of-basis (Transition) matrix. [9L]

Module III

Eigenvalues and eigenvectors, characteristic and minimal polynomials. Eigenvalues of symmetric, skew symmetric, orthogonal and unitary matrices, Diagonalization and triangular form of matrices. [9L]

Module IV

Introduction to Jordan blocks and matrices in Jordon canonical form (examples only). An algorithm to find Jordan form of a square matrix (No proof). Inner product spaces over R (real numbers) and C (complex numbers), Norm of a vector, Schwarz's Inequality, Triangle inequality. [9L]

Module V

Orthogonality of vectors, orthogonal sets and basis, Parallelogram law, Bessel's inequality, Gram-Schmidt orthogonalization process, Orthogonal projection. [9L]

Text Books:

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

Reference Books

1. Gilbert Strang: Introduction to Linear Algebra, Wellesley-Cambridge press
2. Shanti Narayan and P.K Mittal: A text book of Matrices, S. Chand.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Numerical solution system of linear equations
2. Numerical approximation of eigenvalues

POs met through Gaps in the Syllabus

3,4,12

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

<u>Course outcome (co) attainment assessment tools & evaluation procedure</u>

<u>Direct assessment</u>

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 209
Course title: Integral Equations and Green's Function
Pre-requisite(s): Laplace Transform, Ordinary Differential Equation and Partial Differential Equation, Basic Linear Algebra.
Co- requisite(s): ---
Credits: L: 3 T: 1 P:0 C: 4
Class schedule per week: 3 Lectures, 1 tutorial
Class: IMSc.
Semester / Level: IV/ 2
Branch: Mathematics and Computing
Name of Teacher:

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.
CO2.	obtain integral equation from ODE and PDE arising in applied mathematics and different engineering branches and solve accordingly using various method of solving integral equation.
CO3.	construct Green function in solving boundary value problem by converting it to a integral equation
CO4.	apply the knowledge of integral transformation like Laplace transformation, Fourier transformation to solve different types of integral equation.

CO5.	demonstrate a depth of understanding in advanced mathematical topics and solve the complex mathematical problems using the knowledge of Integral equations.

Syllabus

MA209 **Integral Equations and Green's Function** **3-1-0-4**

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.

[9L]

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. [9L]

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. [9L]

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.

[9L]

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. [9L]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements):

1. Problems related to social and environmental issues are not addressed.
2. Singular Integral equations

POs met through Gaps in the Syllabus

5, 10, 11, 12

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design : NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	3	2	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	3	2	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	3	2	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 and CD8
CO2	CD1, CD2 and CD8
CO3	CD1, CD2 and CD8
CO4	CD1 , CD2 and CD8
CO5	CD2 , CD3 and CD4

COURSE INFORMATION SHEET

Course code: MA 301
Course title: Probability and Statistics
Pre-requisite(s): NIL
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, I tutorial.
Class: IMSc.
Semester / Level: V/ 3
Branch: Mathematics and Computing
Name of Teacher:
Course Objectives: This course enables the students to understand

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

MA301 **Probability and Statistics** **3-1-0-4**

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. [9L]

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. [9L]

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. [9L]

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. [9L]

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 variance. [9L]

Text Books

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Applied probability as applied to industries
2. Industrial Statistics

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Simulation of probability distributions
2. Probability and Measure

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	3	2	1	1	1	1	3	2	3	2	2	3	2
CO2	3	3	3	3	2	1	1	1	1	3	3	2	3	2	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	3	3	2
CO4	2	2	2	3	3	1	1	1	1	3	3	2	3	3	3
CO5	2	2	2	3	3	1	1	1	1	3	3	1	3	2	2

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2
CO4	CD1, CD2
CO5	CD1, CD2

COURSE INFORMATION SHEET

Course code: MA 302
Course title: Probability and Statistics Lab
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 0 T: 0 P: 3 C:1.5
Class schedule per week: 03
Class: IMSc.
Semester / Level: V/3
Branch: Mathematics and Computing
Name of Teacher:
Course Objectives: This course enables the students to

1.	Learn how to descriptive a given data by computing statistical summary measures
2.	Learn how to fit suitable probability distributions to a given data
3.	Learn to evaluate correlation coefficient and fit regression lines for a given data
4.	Learn to test the normality of a given data
5.	Learn several tests of significance

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

CO1	compute descriptive measures for a given data
CO2	fit suitable probability distributions to a given data
CO3	compute correlation coefficient and fit regression lines for a given data
CO4	test the normality of a given data
CO5	perform suitable tests of significance as demanded by the problem

List of Practicals
(Using MS-EXCEL / SPSS / R)

1. Determination of Mean, Variance and Coefficient of Variation for a given set of observations.
2. Fitting of Binomial and Poisson distributions.
3. Fitting of a straight line to given data using Principle of Least Squares.
4. Calculation of correlation coefficients for bivariate data and interpretation of results.
5. Determination of two lines of regression for bivariate data.
6. Normality Test of data
7. Spearman's rank Correlation coefficient and Pearson's Correlation coefficient.
8. Testing of goodness of fit by applying Chi-Square Distribution.
9. Testing of independence of attributes by applying Chi-Square Distribution.
10. Interval estimation for Mean and Variance of a Normal Distribution.
11. Interval estimation for a Population Proportion.
12. Testing of single Mean and two Means.
13. Testing of single Variance and two Variances.
14. Testing of Population Proportion(s).

Text Books

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.

Gaps in the Syllabus (to meet Industry/Profession requirements):NA

POs met through Gaps in the Syllabus

3, 4, 12

Topics beyond syllabus/Advanced topics/Design : NA

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	% Distribution
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	√	√	√		
Semester End Examination	√	√	√	√	√

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	1	3	1	1	1	2	1	1	2	3	2	3
CO2	3	2	3	2	2	1	1	1	2	2	3	2	3	2	3
CO3	3	3	2	3	1	1	2	1	2	3	3	2	2	3	3
CO4	2	3	2	3	3	2	1	1	1	3	3	3	2	3	3
CO5	3	2	3	3	3	1	2	1	1	3	3	1	2	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD5
CO2	CD1 and CD5
CO3	CD1, CD5
CO4	CD1 and CD5
CO5	CD1 and CD5

COURSE INFORMATION SHEET

Course code: MA303

Course title: FUZZY LOGIC

Pre-requisite(s): A basic knowledge of set theory would be helpful in understanding operations and properties of fuzzy sets

Co- requisite(s): ---

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

Class schedule per week: 3 Lectures, 1 Tutorial

Class: IMSc

Semester / Level: V/3

Branch: Mathematics and Computing

Name of Teacher:

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

MA303 Fuzzy Logic 3-1-0-4

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, Fuzzification and Defuzzification. [9L]

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. [9L]

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. [9L]

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. [9L]

Module V

Decision Making in Fuzzy Environment: Fuzzy Decisions, Fuzzy Linear Programming, Symmetric Fuzzy LP, Fuzzy LP with crisp objective Function. Applications: Fuzzy Approach to Transportation Problem, Fuzzy sets model in inventory control. [9L]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA

POs met through Gaps in the Syllabus: NA

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	2	1	1	1	1	3	2	3	2	3	3	3
CO2	3	3	3	3	2	1	1	1	1	3	3	2	3	2	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO4	3	2	2	3	3	1	1	1	1	3	3	2	3	2	3
CO5	3	2	2	3	3	1	1	1	1	3	3	1	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD3, CD4
CO2	CD1 , CD2, CD3,CD4
CO3	CD1, CD2, CD3

CO4	CD1, CD2, CD3, CD4
CO5	CD1, CD2, CD3, CD4

COURSE INFORMATION SHEET

Course code: MA 309
Course title: Optimization Techniques
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, 1 Tutorial
Class: IMSc.
Semester / Level: VI / 3
Branch: Mathematics and Computing
Name of Teacher:

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

1	Mathematical Formulation of LPP, Solution of LPP: Graphical Method with special cases, Simplex Method, Big-M Method, Two Phase method. Special cases in simplex method, Duality theory, Dual Simplex algorithm, Post-optimal Analysis: cases of changes in objective function and right hand side parameter of the constraints.
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, Solution of Travelling salesman Problem by integer programming.
4	Network and basic components, Determination of critical path: Critical Path Method (CPM),Project Evaluation and Review Techniques(PERT).Time-cost optimization Algorithm.
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 a 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

MA309 Optimization Techniques 3-1-0-4

Module I

Linear Programming Problem (LPP): Mathematical Formulation of LPP, Solution of LPP: Graphical Method with special cases, Simplex Method, Big-M Method, Two Phase method. Special cases in simplex method, Duality theory, Dual Simplex algorithm, Post-optimal Analysis: cases of changes in objective function and right hand side parameter of the constraints. [9L]

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. [9L]

Module III

Advanced Linear Programming: Revised Simplex Method, Parametric Linear Programming, Integer Linear Programming: Branch and Bound Method, Cutting Plane Method, Solution of Travelling salesman Problem by integer programming. [9L]

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).Time-cost optimization Algorithm. [9L]

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. [9L]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements) :NA
POs met through Gaps in the Syllabus :NA
Topics beyond syllabus/Advanced topics/Design
Solving Travelling Salesman Problem using Heuristic Algorithms
POs met through Topics beyond syllabus/Advanced topics/Design
1,2,3,4,10,12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	3	2	1	1	1	1	3	2	3	2	3	3	3
CO2	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO4	2	2	2	3	3	1	1	1	1	3	3	2	3	3	3
CO5	2	2	2	3	3	1	1	1	1	3	3	1	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD6, CD7, CD 8
CO2	CD1, CD2, CD6, CD8, CD9
CO3	CD1, CD2, CD3, CD6 and CD 8
CO4	CD1, CD2, CD6, CD8
CO5	CD1, CD2, CD6, CD8

COURSE INFORMATION SHEET

Course code: MA 310
Course title: Optimization Techniques Lab
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 0 T: 0 P: 3 C:1.5
Class schedule per week: 3 Sessional
Class: IMSc.
Semester / Level: VI / 3
Branch: Mathematics and Computing
Name of Teacher:

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

1	Mathematical Formulation of LPP, Solution of LPP: Graphical Method with special cases, Simplex Method, Big-M Method, Two Phase method. Special cases in simplex method, Duality theory, Dual Simplex algorithm, Post-optimal Analysis: cases of changes in objective function and right hand side parameter of the constraints.
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, Solution of Travelling salesman Problem by integer programming.
4	Network and basic components, Determination of critical path: Critical Path Method (CPM),Project Evaluation and Review Techniques(PERT).Time-cost optimization Algorithm.
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 a 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 a 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.

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

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

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	% Distribution
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment	√	√	√		
Semester End Examination	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	2	1	1	1	1	3	2	3	2	3	3	3
CO2	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO4	2	2	2	3	3	1	1	1	1	3	3	2	3	3	3
CO5	2	2	2	3	3	1	1	1	1	3	3	1	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD3, CD5, CD6
CO2	CD1, CD2, CD3, CD5, CD6, CD8, CD9
CO3	CD1, CD2, CD3, CD5, CD6, CD8 and CD9
CO4	CD1, CD2, CD3, CD5, CD6, CD8,CD9

CO5	CD1 , CD2,CD5, CD6, CD8,CD9

COURSE INFORMATION SHEET

Course code: MA 311
Course title: Numerical Techniques
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, 1 Tutorial
Class: IMSc.
Semester / Level: VI / 3
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to

1.	derive appropriate numerical methods to solve algebraic and transcendental equations
2.	derive appropriate numerical methods to solve linear system of equations
3.	approximate a function using various interpolation techniques
4.	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 numerically

Syllabus

MA311 **Numerical Techniques** 3-1-0-4

Module I

Definition and sources of errors, propagation of errors, backward error analysis, sensitivity and conditioning, stability and accuracy, 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. [9L]

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. [9L]

Module III

Lagrange's interpolation, Newton's divided differences interpolation formulas, inverse interpolation, interpolating polynomial using finite differences, Hermite interpolation, Piecewise interpolation, spline interpolation, B-splines, cubic splines and function approximations by least squares and uniform approximations. [9L]

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, Predictor-Corrector methods (Milne & Adams-Bashforth) to solve initial value problems, Shooting and finite difference methods for boundary value problems. [10L]

Text Books

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

Gaps in the Syllabus (to meet Industry/Profession requirements) : NA

POs met through Gaps in the Syllabus

3, 4, 12

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 12

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

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

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

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	2	1	1	1	1	3	2	3	2	2	3	3
CO2	3	3	3	3	2	1	1	1	1	3	3	2	2	3	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	2	3	3
CO4	2	2	2	3	3	1	1	1	1	3	3	2	2	3	3
CO5	2	2	2	3	3	1	1	1	1	3	3	1	2	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 312
Course title: Numerical Techniques Lab
Pre-requisite(s):
Co- requisite(s): ---
Credits: L: 0 T: 0 P: 3 C:1.5
Class schedule per week: 03 Sessional.
Class: IMSc.
Semester / Level: VI/ 3
Branch: Mathematics and Computing
Name of Teacher:

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

MA312 **Numerical Techniques Lab** **(0-0-3-1.5)**

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 $f(x, y) = -2xy^2$.

Text Books

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

Gaps in the Syllabus (to meet Industry/Profession requirements) : NA

POs met through Gaps in the Syllabus

3, 4, 12

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 12

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

<u>Direct Assessment</u>

Assessment Tool	**% Contribution during CO Assessment**
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	**% Distribution**
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	**% Distribution**
Examination Experiment Performance	30
Quiz	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment	√	√	√		
Semester End Examination	√	√	√	√	√

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	3	1	3	1	1	1	2	1	1	2	2	3	3
CO2	3	2	3	2	2	1	1	1	2	2	3	2	2	3	3
CO3	3	3	2	3	1	1	2	1	2	3	3	2	2	3	3
CO4	2	3	2	3	3	2	1	1	1	3	3	3	2	3	3
CO5	3	2	3	3	3	1	2	1	1	3	3	1	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD5
CO2	CD1 and CD5
CO3	CD1, CD5 and CD8
CO4	CD1 and CD5
CO5	CD1 and CD5

COURSE INFORMATION SHEET

Course code: MA 401
Course title: Real Analysis and Measure Theory
Pre-requisite(s): Basics of real analysis, Riemann Integration.
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 3 Lectures, 1 Tutorial.
Class: IMSc/ MSc
Semester / Level: VII / 4
Branch: Mathematics and Computing/Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	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

MA401 **Real Analysis and Measure Theory** **3-1-0-4**

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. [9L]

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. [9L]

Module III

Borel Sets, σ-ring, σ-algebra, Lebesgue outer measure, measurable sets and their properties, Lebesgue measure, measurable function. [9L]

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). [9L]

Module V

Monotone convergence theorem and its consequences, Fatou's lemma, Lebesgue dominated convergence theorem, Comparison of Lebesgue integral and Riemann integral. [9L]

Text Book:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design
All fixed point theorems related to Functional Analysis
POs met through Topics beyond syllabus/Advanced topics/Design
2, 3

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

<u>Direct Assessment</u>

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

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

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	1	1	1	2	2	3	3	3	1	1	2	3	3
CO2	3	3	1	1	1	2	2	3	3	3	1	1	2	3	3
CO3	3	3	1	1	3	2	2	3	3	3	1	2	2	3	3
CO4	3	3	2	1	1	2	2	3	3	3	2	2	2	3	3
CO5	3	3	2	1	1	2	2	3	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 402
Course title: Advanced Complex Analysis
Pre-requisite(s): Basics of Complex Variable Functions
Co- requisite(s): ---
Credits: L: 3 T: 1 P:0 C:4
Class schedule per week: 3 Lectures, 1 Tutorial.
Class: IMSc/MSc
Semester / Level: VII / 4
Branch: Mathematics and Computing/ Mathematics
Name of Teacher:

Course Objectives : This course enables the students to understand

1.	the complex differentiation and integration of analytic functions
2.	the convergence and divergence of series of complex variable functions, with special emphasis on Taylor and Laurent series
3.	the theory behind multivalued functions associated with complex variables
4.	the 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 remarkable properties of complex variable functions, which are not the features of their real analogues
CO2	acquire knowledge about different types of functions viz. analytic, entire and meromorphic functions occur in complex analysis along with their properties
CO3	apply the knowledge of complex analysis in diverse fields related to mathematics
CO4	utilize the concepts of complex analysis to specific research problems in mathematics or other fields.
CO5	enhance and develop the ability of using the language of mathematics in analyzing the real-world problems of sciences and engineering.

Syllabus

MA402 **Advanced Complex Analysis** 3-1-0-4

Module I

Topology of the complex plane, functions on the complex plane, Stereographic projection
Holomorphic (analytic) functions, Cauchy - Riemann equations, Integration of complex variable functions along curves, parameterization of curves, smooth curve, contours, contour Integrals and their properties, Cauchy's Theorem, Goursat Theorem, Cauchy – Integral Formula, Cauchy Integral Formula for derivatives, Cauchy's Inequality, Morera's theorem, Liouville's theorem. [10L]

Module II

Conformal mapping, fractional transformation, Riemann mapping theorem, Schwartz – Christoffel transformation
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 series, Laurent series, Analytic continuation. [9L]

Module III

Zeros of analytic function, singularities of analytic function and their different types, Residues, Residue theorem. Multivalued functions, branch point, branch cut, evaluation of integrals involving branch point using calculus of residues. [9L]

Module IV

Meromorphic function and its properties, zeros and poles of meromorphic function, Riemann sphere, winding number, Argument principle, Rouche's theorem and its applications, Identity theorem, Schwarz's lemma, Maximum Modulus theorem, Fundamental theorem of algebra. [9L]

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, Jensen's formula, functions of finite order. [8L]

Text Books:

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. Reinhold Remmert, Theory of Complex Functions, Springer International Edition, 1991.

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.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Applications of complex variable theory in different real life situations

POs met through Gaps in the Syllabus

2,3,9

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

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

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

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD2, CD3
CO4	CD3, CD4
CO5	CD3, CD4

COURSE INFORMATION SHEET

Course code: MA 412
Course title: Topology
Pre-requisite(s): Basics of real Analysis and Functional Analysis
Co- requisite(s): ---
Credits: L: 3 T: 1 P: 0 C:4
Class schedule per week: 03 Lectures, 1 Tutorial
Class: IMSc/ MSc
Semester / Level: VIII/4
Branch: Mathematics and Computing/ Mathematics
Name of Teacher:

Course Objectives: This course enables the students to understand

1.	The concept of a Topological space which generalizes the spaces arising in Real and Functional Analysis
2.	The generalization of the concept of continuity on Topological spaces
3.	The 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

MA412 **Topology** 3-1-0-4

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. [9L]

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. [9L]

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. [9L]

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. [9L]

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. [9L]

Text Book:

1. J. R. Munkres – Topology :Pearson New International Edition, 2nd 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.

Gaps in the Syllabus (to meet Industry/Profession requirements)

Machine Learning, Shape Recognition

POs met through Gaps in the Syllabus

3,4,12

Topics beyond syllabus/Advanced topics/Design

Topological approach to study solutions of mathematical models in Real World Problems.

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3,12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	3	2	1	2	2	2	2	3	3	2	3	3
CO2	3	3	2	2	2	1	2	2	2	2	3	3	2	3	3
CO3	3	2	1	1	1	1	2	1	2	2	3	2	2	3	3
CO4	3	2	1	2	1	1	2	1	2	2	3	2	2	3	3
CO5	3	2	2	2	1	1	2	1	2	2	2	3	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

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. **[10L]**

Module II

Definition of a stochastic process, classification of a stochastic process, applications in queues, birth and death processes, concept of stationarity, Gaussian process. **[10L]**

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. **[10L]**

Module IV

Poisson Process and its postulates, properties and applications, Renewal process, Diffusion process and Brownian motion. **[10L]**

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). **[10L]**

Text Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Advanced stochastic processes as demanded in industries

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Simulation of skew-normal, skew-t distributions

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4, 12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	3	2

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 414
Course title: Advanced Operations Research
Pre-requisite(s): Optimization Techniques, Introductory statistics, linear algebra and calculus.
Co-requisite(s): -
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 Lectures 1 tutorial
Class: IMSc /MSc
Semester: VIII / 4
Branch: Mathematics and Computing/Mathematics
Name of the Faculty:

Course Objectives: This course enables the students to understand

1.	dynamic programming concepts
2.	deterministic as well as stochastic inventory problems
3.	decision making problems under various decision making environments
4.	performance measures of queuing systems
5	non-linear programming concepts

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

CO1	Conceptualize various dynamic programming models and their applications in solving multi-stage decision problems.
CO2	Determine economic order quantity (EOQ) for minimizing total inventory cost, and handle inventory problems with probabilistic demand to determine EOQ.
CO3	Make decision under various decision making environments like certainty, risk and uncertainty; and determine strategies to win a game.
CO4	Analyze various performance measures of queuing systems and derive those performance measures for single server and multiple server queuing models.
CO5	Solve constrained optimization problems with equality as well as inequality constraints.

Syllabus

MA414 | Advanced Operation Research | 3-1-0-4

Module I

Dynamic Programming:

Introduction of Dynamic Programming, Deterministic Dynamic Programming: Forward and Backward Recursion, Selected DP Applications: Cargo load problem, Equipment Replacement Problem, Reliability problem. Solution of linear programming problem by dynamic programming. [9L]

Module II

Inventory Models:

Deterministic Inventory Models: General Inventory Models, Static EOQ models: classical EOQ model (EOQ without shortage), EOQ with shortage, EOQ with price breaks, multi-item EOQ with storage limitations. Dynamic EOQ models: No set-up model; set-up model.

Stochastic Inventory Models: Probabilistic EOQ models; Single period models, Multi period models. [9L]

Module III

Decision Analysis and Games:

Decision making under certainty, Decision making under risk, Decision Tree Analysis, Utility theory, Decision making under uncertainty.

Game Theory: Optimal Solution of Two – person Zero-Sum games, Solution of mixed strategy games. [9L]

Module IV

Queuing Systems:

Queue, Elements of queuing model, 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)},Non Poisson queuing system (Erlangian service time distribution). [9L]

Module V

Non-linear Programming:

Unconstrained Algorithm: Direct search Method and Gradient Method, Constraint Optimization with equality constraints (Lagrange's Multiplier Method), Constraint Optimization with inequality constraints(Kuhn Tucker Conditions),Quadratic Programming (Wolfe's Method), Separable Programming, Goal Programming. [9L]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (CO) attainment

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	3	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	3	3	3	1	1	1	1	3	3	1	2	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1,CD2,CD3,CD4,CD5, CD6,CD7, CD 8
CO2	CD1,CD2,CD3,CD4, CD5,CD6,CD8,CD9
CO3	CD1, CD2, CD3,CD4,CD5,CD6 and CD 8
CO4	CD1 ,CD2,CD3,CD4,CD5,CD6, CD8
CO5	CD1 , CD2,CD3,CD4,CD5,CD6, CD8

COURSE INFORMATION SHEET

Course code: MA 415
Course title: Advanced Operations Research Lab
Pre-requisite(s): Knowledge of software like TORA, LINGO, Excel, Matlab
Co-requisite(s): -
Credits: L:0 T:0 P:3 C:1.5
Class schedule per week: 3 Sessionals
Class: IMSc.
Semester/Level: VIII / 4
Branch: Mathematics and Computing
Course Coordinator:
Course Objectives: This course enables the students to understand

1.	dynamic programming concepts
2.	deterministic as well as stochastic inventory problems
3.	decision making problems under various decision making environments
4.	performance measures of queuing systems
5.	non-linear programming concepts

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

CO 1	Conceptualize various dynamic programming models and their applications in solving multi-stage decision problems.
CO 2	Determine economic order quantity (EOQ) for minimizing total inventory cost, and handle inventory problems with probabilistic demand to determine EOQ.
CO 3	Make decision under various decision making environments like certainty, risk and uncertainty; 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	Solve constrained optimization problems with equality as well as inequality constraints.

List of Assignments:

The following types of problems have to be solved by TORA, LINGO, Excel, or MATLAB as applicable:

1. Solution of shortest-route problems.
2. Solution of LPP using dynamic programming.
3. Computation of economic order quantity (EOQ) for deterministic inventory models.
4. Solution of decision making problem under certainty – Analytical Hierarchy Process (AHP)
5. Solution of mixed strategy games by graphical method.
6. Solution of single server (M/M/1) and multiple sever (M/M/S) queuing problems (Poisson queuing systems).
7. Solution of constraint optimization problems with equality constraints.
8. Solution of constraint optimization problems with inequality constraints.
9. Solution of goal programming problems.
10. Solution of quadratic programming problems.

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

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

<u>Direct Assessment</u>

Assessment Tool	**% Contribution during CO Assessment**
Continuous Internal Assessment	60
Semester End Examination	40

Continuous Internal Assessment	**% Distribution**
Day to day performance & Lab files	30
Quiz (es)	10
Viva	20

Semester End Examination	**% Distribution**
Examination Experiment Performance	30
Quiz	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment	√	√	√		
Semester End Examination	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	3	2	1	1	1	1	3	2	3	2	3	3	3
CO2	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	3	3	3
CO4	2	2	2	3	3	1	1	1	1	3	3	2	3	3	3
CO5	2	2	2	3	3	1	1	1	1	3	3	1	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD3, CD5, CD6
CO2	CD1 , CD2,CD3,CD5, CD6, CD8, CD9
CO3	CD1, CD2,CD3,CD5 , CD6,CD8 and CD9
CO4	CD1 , CD2,CD3,CD5, CD6,CD8,CD9
CO5	CD1 , CD2,CD5, CD6, CD8,CD9

COURSE INFORMATION SHEET

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

Course Objectives: This course enables the students to understand

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

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

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

Syllabus

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

Module I

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

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

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

Module II

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

Module III

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

Module IV

Hilbert spaces: Inner product spaces, Polarization identity, Jordan Von-Neumann theorem, Parallelogram law, Schwarz's inequality. Hilbert space, orthonormal set, Pythagoras theorem, The Gram-Schmidt orthogonalization theorem, Bessel inequality, Orthonormal basis, Fourier expansion and Parseval's formulae. Projection theorem, Riesz Representation theorem, unique Hanh- Banach extension theorem. [8L]

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus : NA
Topics beyond syllabus/Advanced topics/Design

1. All fixed point theorems related to Fractional Calculus

POs met through Topics beyond syllabus/Advanced topics/Design
2, 3

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	3	2	1	2	2	2	2	3	3	2	3	3
CO2	3	3	2	2	2	1	2	2	2	2	3	3	2	3	3
CO3	3	2	1	1	1	1	2	1	2	2	3	2	2	3	3
CO4	3	2	1	2	1	1	2	1	2	2	3	2	2	3	3
CO5	3	2	2	2	1	1	2	1	2	2	2	3	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

Course Objectives : This course enables the students to

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

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

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]

Text Books

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

Reference Books

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Applications to cyber security

POs met through Gaps in the Syllabus

3,12

Topics beyond syllabus/Advanced topics/Design

1. Group and Ring Theory

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 12

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

<u>Direct Assessment</u>

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	3	1	1	1	3	3	3	2	2	2	3	3
CO2	3	3	3	3	1	1	1	3	3	3	2	2	2	3	3
CO3	3	3	3	3	1	1	1	3	3	3	2	2	2	3	3
CO4	3	3	3	3	1	1	1	3	3	3	2	2	2	3	3
CO5	3	3	3	3	1	1	1	3	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

Detail Course Structures

of

PROGRAM SPECIFIC ELECTIVES (PE)

COURSE INFORMATION SHEET

Course code: MA 304
Course title: Tensor Analysis
Pre-requisite(s): Vector Analysis
Co- requisite(s): ---
Credits: L: 3 T: 1 P:0 C:4
Class schedule per week: 3 Lectures 1 Tutorial
Class: IMSc.
Semester / Level: V / 3
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives

This course enables the students to understand

1.	tensors, difference between contravariant and covariant tensors and their algebraic properties
2.	importance of Riemannian metric in n – dimensional space, calculus of tensors in Riemannian space
3.	derivatives of covariant and contravariant tensors, along with concept of gradient, divergence and curl in Riemannian space
4.	special types of tensors like curvature, Ricci tensor etc. and different properties associated with them
5.	applications of tensors analysis in diverse fields

Course Outcomes

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

CO1.	understand tensors and its difference with scalars and vectors
CO2.	demonstrate the properties associated with covariant and contravariant tensors
CO3.	develop the understanding of Riemannian space and its properties of tensors in it
CO4.	gain an understanding to solve problems with the use of tensors to diverse situations in mathematical contexts
CO5.	work efficiently in multi - disciplinary research areas of sciences and engineering

Syllabus

MA304 **Tensor Analysis** **3-1-0-4**

Module I

Tensor Algebra: Preliminaries: systems of different orders, indicial and summation convention, Kronecker symbols. Introduction to tensors, n – dimensional space, transformation of coordinates, invariants, covariant vectors, contravariant vectors, second order contravariant, covariant and mixed tensors, Higher order tensors, Zero tensor, Tensor field. Addition and Subtraction of tensors, Equality of tensors, Symmetric and Skew Symmetric tensors, Contraction, Multiplication of tensors – Outer Product, Inner Product, Quotient Law, Conjugate (Reciprocal) tensors of second order. [10L]

Module II

Riemannian Metric: Line Element, Riemannian metric, fundamental metric tensor and its properties, Riemannian space, Conjugate (or reciprocal) of fundamental metric tensor, Associated Tensors, Length of a curve, Magnitude of a vector, Angle between vectors, Orthogonality. [10L]

Module III

Christoffel Symbols: Christoffel symbols of first and second kind, Properties of Christoffel Symbols, Law of transformations of Christoffel symbols of first and second kind. [9L]

Module IV

Covariant Differentiation: Covariant Differentiation of Covariant and Contravariant vectors, Covariant differentiation of second and higher order tensors, Properties of covariant differentiation, Ricci's theorem, gradient, divergence and curl in tensorial forms, intrinsic derivative. [8L]

Module V

Curvature Tensors: Riemann Christoffel tensor, Curvature tensor, properties of Riemann – Christoffel Curvature tensor, Bianchi identities, Ricci tensor, Riemannian curvature, Flat space, space of constant curvature, Einstein space, Einstein tensor. [8L]

Text Books:

1. Barry Spain, Tensor Calculus: A Concise Course, Dover Publications, New York, 2003.
2. David Kay, Schuam's Outline of Tensor Calculus, Tata Mcgraw Hill Publishers, 2011.

Reference Books:

1. L.P. Eisenhart, Riemannian Geometry, Princeton University Press, 1949.
2. J.G. Simmonds, A Brief on Tensor Analysis, Springer - Verlag Publishers, 1982.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. curvilinear coordinates
2. special types of tensors that occur in sciences and engineering

POs met through Gaps in the Syllabus

2, 3, 9

Topics beyond syllabus/Advanced topics/Design: : NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	
Quiz (s)	√	√	√		
Assignment	√	√	√	√	√

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2
CO4	CD3, CD4
CO5	CD3,CD4

COURSE INFORMATION SHEET

Course code: MA 305
Course title: Graph Theory
Pre-requisite(s): MA205
Co- requisite(s):
Credits: 4 L:3 T:1 P:0 C:4
Class schedule per week: 03 Lectures, 1 tutorial
Class: IMSc.
Semester / Level: V / 3
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives : This course enables the students to:

1.	cover basic concepts in graph theory and a variety of different problems in Graph Theory
2.	come across a number of theorems and proofs. Theorems will be stated and proved formally using various techniques.
3.	gain the knowledge of Various concepts in graph theory like, planarity, graph coloring, domination number.
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 *the* basic notions and definitions in graph theory,
CO2	understand various types of trees and methods for traversing trees.
CO3	understand the concepts of graph coloring and different types of coloring of graphs.
CO4	understand the relation between graph theory and real world problems
CO5	apply the algorithms that are treated in the course for solving graph theoretical problems

Syllabus

MA 305 **Graph Theory** **3-1-0-4**

Module I

Introduction to Graphs: Definition of a Graph, Finite and Infinite Graphs, Incidence of vertices and edges, Types of Graphs, Sub Graphs, Digraphs, Bipartite Graphs, Isomorphism of Graphs, Degrees of Vertices, Handshaking Lemma, Matrix representation of Graphs: Adjacency Matrix, Incidence Matrix. [9L]

Module II

Connectedness : Walks, Trail, Paths. Connectivity: Cut vertex, Cut edge, Vertex connectivity, and Edge connectivity. Eulerian Graphs, Hamiltonian Graphs, Necessary condition for Hamiltonian Graph, Ore's Theorem, Dirac's Theorem, Operations on Graphs: Union of Graphs, Intersection of Graphs and Join of Graphs.

Planarity: Definition, Euler's Formula and its consequences, Kuratowski's Theorem and it's applications. [9L]

Module III

Independent Sets and Matchings: Vertex-Independent Sets and Vertex Coverings, Edge-Independent Set, Matchings and Factors, Matchings in Bipartite Graphs, Perfect Matchings [9L]

Module IV

Graph Colorings: Vertex Coloring, Chromatic number, Edge Coloring, Chromatic Index, Chromatic Polynomials.

Domination in Graphs: Domination in Graphs, Bounds for the Domination Number [9L]

Module V

Trees: Definition, Directed Tree, 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.

Spectral Properties of Graphs: The Spectrum of a Graph, Spectrum of the Complete Graph, Spectrum of the Cycle. [9L]

Text 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. West, Douglas Brent. Introduction to graph theory. Vol. 2. Upper Saddle River: Prentice hall, 2001.

Reference Books:

1. Harary, Frank. "Graph theory". 1969.
2. Bondy J. A. and Murty U. S. R., "Graph Theory", Springer, 2011
3. Deo N., "Graph Theory with Applications to Engineering and Computer Science", Prentice Hall India, 2004
4. Deistel R., "Graph Theory", Springer (4th Ed.) 2010

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Chromatic number for different types of graphs.
2. Application of Graph coloring.
3. Duality of planar graphs and its applications.

POs met through Gaps in the Syllabus

3, 4, 10

Topics beyond syllabus/Advanced topics/Design

1. Line graph and its properties
2. Automorphism of graphs
3. Network flows and optimizations

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 10, 12

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√	√	
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, and CD 8
CO2	CD1 and CD8
CO3	CD1, CD2 and CD3
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 306
Course title: Special Functions
Pre-requisite(s): Ordinary differential equations
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 lectures, 1 Tutorial
Class: IMSc.
Semester/level: V/ 3
Branch: Mathematics and Computing
Name of the Faculty:

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

1.	Orthogonal set of functions, its orthogonalization. Sturm-Liouville Problem, eigen functions and its properties.
2.	hypergeometric function, the most general of all the special functions.
3.	the Hermite polynomials and Laguerre polynomials with their properties.
4.	Chebyshev polynomials with their properties.

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

CO1.	deal with the problem of evaluating the solution of differential equations arise in real world phenomenon where the solutions are not in terms of elementary functions, which leads to the series solutions, new functions as special functions.
CO2.	use the Hermite polynomials and its result in solving problems related to quantum-mechanical harmonic oscillator. use the Laguerre polynomials and its result in solving problems related to quantum-mechanical study of the hydrogen atom, transmission line theory and seismological investigations.
CO3	use Chebyshev polynomials in polynomial approximations to arbitrary functions and also in electrical circuit theory.
CO4.	use the principal results concerning special functions likely to be encountered in applications to the particular context in which they arise.
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

MA306 **Special Functions** **3-1-0-4**

Module I

Orthogonal Set of Functions: Introduction, Definitions, Orthogonal Functions, Gram-Schmidt Process of Orthogonalization, Orthogonality with respect to Weight Function, Orthonormal set of Functions with respect to weight Function, Application of Orthogonality (Generalised Fourier Series and Fourier constants), Sturm-Liouville Problem, Eigen Functions, Properties of Eigen-Function and Eigen values. [10L]

Module II

Hypergeometric Functions: Introduction, Hypergeometric Differential Equation, Simple and Quadratic Transformations of Hypergeometric Function, Generalised Hypergeometric Function, Integrals involving Generalised Hypergeometric Function, Some Special Generalised Hypergeometric Functions. [10L]

Module III

Hermite Polynomials: Introduction, Solution of Hermite's Differential Equation, Hermite Polynomials, Generating Function, Value of $H_n(x)$ and its Derivative at $x = 0$, Rodrigues Formula for $H_n(x)$, First Few Polynomials, Recurrence Relations for $H_n(x)$, lntegral Representation of Hermite Polynomial, Orthogonal Properties of $H_n(x)$. [9L]

Module IV

Laguerre Polynomials: Introduction, Solution of Laguerre's Differential Equation, Generating Function, Generating Function, Rodrigues Formula for $L_n(x)$, Recurrence Relations, Laguerre Polynomials for particular values of n and x, Orthogonal Property of $L_n(x)$, Integral relations of $L_n(x)$. [8L]

Module V

Chebyshev Polynomials: Introduction, Independent Solutions of Chebyshev's Equation, Expansion of $T_n(x)$ and $U_n(x)$, Generating Functions, Recurrence Relations, Evaluation of $T_n(x)$ and $U_n(x)$ for given values of n, Orthogonal Properties of $T_n(x)$ and $U_n(x)$, A brief Exposure of Advanced Special Function like, Elliptic Functions, Mathieu Functions, Spheroidal Functions etc. [8L]

Text Books:

1. W. W. BELL , Special Functions For Scientists And Engineers , D. Van Nostrand Company Ltd, 1968
2. Nico M. Temme, Special Functions: An Introduction to the Classical Functions of Mathematical Physics, John Wiley & Sons, Inc., 1996

Reference Books:

1. Special Functions and Their Applications. N. N. Lebedev. Translated from the revised Russian ed. (Moscow, 1963) by Richard A. Silverman. Prentice-Hall, Englewood Cliffs, N.J., 1965.

Gaps in the Syllabus (to meet Industry/Profession requirements):

1. Problems related to Social and environmental issues are not addressed.

POs met through Gaps in the Syllabus

5, 10, 11, 12

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

<u>Course outcome (co) attainment assessment tools & evaluation procedure</u>

<u>Direct assessment</u>

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	3	2	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	3	2	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	3	2	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

Mapping Between COs and Course Delivery (CD) methods

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 and CD8
CO2	CD1, CD2 and CD8
CO3	CD1, CD2 and CD8
CO4	CD1 CD2 and CD8
CO5	CD2, CD3 and CD4

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: I MSc.
Semester/level: V/3
Branch: Mathematics and Computing
Name of the Faculty:

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]

Text Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

<u>Course outcome (co) attainment assessment tools & evaluation procedure</u>

<u>Direct assessment</u>

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 308
Course title: 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: V/ 3
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students to understand

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]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements):NA

POs met through Gaps in the Syllabus: NA

Topics beyond syllabus/Advanced topics/Design

1. Theory of Difference Equations in Statistical models

POs met through Topics beyond syllabus/Advanced topics/Design

2,3,4

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	√

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	2	2	1	1	2	2	3	3	2	2	3	3
CO2	3	3	3	2	2	1	1	2	3	2	2	3	2	3	3
CO3	3	3	3	3	1	1	1	2	3	2	2	3	2	3	3
CO4	3	2	2	3	1	1	1	1	2	2	2	3	2	3	3
CO5	3	3	2	2	1	1	1	1	2	2	2	3	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 313
Course title: Combinatorics
Pre-requisite(s):
Co- requisite(s):
Credits: L:3 T:1 P:0 C: 4
Class schedule per week: 3 Lectures 1 Tutorial
Class: IMSc.
Semester / Level: VI / 3
Branch: Mathematics and Computing
Name of Teacher:

Course Objectives: This course enables the students:

1.	to become familiar with fundamental combinatorial structures that naturally appear in various other fields of mathematics and computer science.
2.	to learn how to prove the existence or non-existence of the object, compute the number of such objects, and understand their underlying structure.

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

CO1.	to model and analyze computational processes using analytic and combinatorial methods
CO2.	to know the limitations of computations and be able to identify infeasibilities and limitations of computational problems.
CO3.	apply counting techniques to solve combinatorial problems and identify, formulate, and solve computational problems in various fields.
CO4.	have a strong background on counting principles
CO5.	apply counting techniques to solve real-world problems of sciences and engineering.

Syllabus

MA313 **Combinatorics** **3-1-0-4**

Module I

Introduction to Principles of Counting**,** The Fundamental of Counting, Multiplication Principle, Addition Rule, Mathematical Induction, Strong Mathematical Induction, Well-ordering Principle, Binomial Theorem, Pascal's Triangle, Multinomial Coefficient. **[9L]**

Module II

Permutations, Permutations with Repetitions, Circular Permutations, Ordered Sampling. Combinations, Combinations of n Different Objects, Combinations with Repetitions, The Pigeonhole Principle, Generalized Pigeonhole Principle, Derangements, Summation Method**.** **[10L]**

Module III

Concept of Congruences and its Elementary Properties, Congruences in one unknown, Complete Residue System, Reduced Residue System, Gauss Function, Mobius Function, Chinese Remainder Theorem, Combinatorial Assignments, Partition of Integers, Euler ϕ-Function, Inclusion-Exclusion Principle, Application of Inclusion-Exclusion Principle. [**10L]**

Module IV

Recurrence Relations: Order and Degree of Recurrence Relation, Linear Homogenous and Non-Homogeneous Recurrence Relations with Constant coefficients and their Solutions, Solution of Non-linear Homogenous and Non-homogeneous Recurrence Relations. [**8L**]

Module V

Generating Functions, Addition and Multiplication of two Generating Functions, Solution of Recurrence Relations using the method of Generating function, Partition by Generating Function, Generating Function for restricted Partitions. [**8L]**

Text Books:

1. Ralph P. Grimaldi: *Discrete and Combinatorial Mathematics – An applied introduction*, Pearson Addison Wesley, 5th Edition, 2004.
2. Bikash Kanti Sarkar and Swapan Kumar Chakraborty: Combinatorics and Graph Theory, PHI, 2016.
3. Kolman, Bernard, Robert C. Busby, and Sharon Ross. *Discrete mathematical structures*. Prentice-Hall, Inc., 2003.

Reference Books:

1. Rosen, Kenneth H. *Handbook of discrete and combinatorial mathematics*. Chapman and Hall/CRC, 2017.
2. Swapan Kumar Chakraborty and Bikash Kanti Sarkar: *Discrete Mathematics*, Oxford Univ. Publication, 2010.
3. Seymour Lipschuz and Mark Lipson: Discrete Mathematics, Shaum's outlines, 2003.
4. Liu, Chung Laung, *Elements of Discrete mathematis*, Mcgraw Hill, 2nd edition, 2001.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Usage Generating functions in inclusion exclusion principle.
2. Fields and finite fields

POs met through Gaps in the Syllabus

3, 4, 10

Topics beyond syllabus/Advanced topics/Design

1. Latin squares and its properties
2. Steiner triple systems and its applications
3. Finite fields and linear algebra over finite fields

POs met through Topics beyond syllabus/Advanced topics/Design

2, 3, 4, 10, 12

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	**% contribution during co assessment**
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD 8
CO2	CD1 and CD8
CO3	CD1, CD2 and CD3
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA314
Course title: Fuzzy Set Theory and Its Applications
Pre-requisite(s): Set theory and classical logic.
Credits: L:4 T:0 P:0 C:4
Class schedule per week: 4 Lectures
Class: IMSc.
Semester: VI/3
Branch: Mathematics and Computing
Course Coordinator:

COURSE DESCRIPTION:

1	Fuzzy Sets, operations and its properties of Fuzzy Sets. Types of Fuzzy Sets. Further Operations on Fuzzy Sets, Aggregation Operators, Fuzzy Measures and Measures of Fuzziness.
2	Fuzzy Relations and its Cardinality, Operations on Fuzzy Relations, Properties of Fuzzy Relations, Fuzzy Cartesian product and Composition .Fuzzy Graphs.
3	The Extension Principle .Operations for Type 2 Fuzzy Sets. Algebraic Operations with Fuzzy Numbers. and Extended Operations for LR-Representation of Fuzzy Sets
4	Classical Logic and Fuzzy Logic.
5	Fuzzy Set Models in Inventory Control, Scheduling, Job-Shop Scheduling and Transportation Problem

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

CO1	learn about Fuzzy Sets, operations on it, aggregation Operators and measures of fuzziness.
CO2	learn about Fuzzy Relations and Operations on Fuzzy Relations.
CO3	learn about The Extension Principle and Applications.
CO4	learn Fuzzy Logic and Approximate Reasoning.
CO5	apply Fuzzy Sets in various areas of application.

Syllabus

MA 314 FUZZY SET THEORY AND ITS APPLICATIONS 3-1-0-4

MODULE I: Fuzzy Sets-Basic Definitions

Classical Sets, Operations on Classical Sets, Properties of Classical (Crisp) Sets, Mapping of Classical Sets to Functions. Fuzzy Sets, Fuzzy Set Operations, Properties of Fuzzy Sets. Types of Fuzzy Sets. Further Operations on Fuzzy Sets. Algebraic Operation. Set-Theoretic Operations. Criteria for Selecting appropriate Aggregation Operators. Fuzzy Measures. Measures of Fuzziness. [9L]

MODULE II: Fuzzy Relations and Fuzzy Graphs

Cartesian Product, Crisp Relations, Cardinality of Crisp Relations, Operations on Crisp Relations , Properties of Crisp Relations ,Composition. Fuzzy Relations, Cardinality of Fuzzy Relations , Operations on Fuzzy Relations, Properties of Fuzzy Relations, Fuzzy Cartesian product and Composition .Fuzzy Graphs. [9L]

MODULE III: The Extension Principle and Applications

The Extension Principle. Operations for Type 2 Fuzzy Sets. Algebraic Operations with Fuzzy Numbers. Special Extended Operations. Extended Operations for LR-Representation of Fuzzy Sets.

[9L]

MODULE IV: Fuzzy Logic and Approximate Reasoning

Classical Logic: Tautologies, Contradictions, Equivalence, Exclusive or and Exclusive Nor, Logical Proofs, Deductive Inferences, Fuzzy Logic, Approximate Reasoning, Other Forms of the Implication Operation. Linguistic Variables, Fuzzy Logic, Fuzzy (Rule-Based) Systems. Graphical Techniques of Inference. [9L]

MODULE V: Applications

Fuzzy Approach to the Transportation Problem, Fuzzy Set Models in Inventory Control. Fuzzy Sets in Scheduling. Job-Shop Scheduling with Expert Systems. A Method to Control Flexible Manufacturing Systems. Scheduling Courses, Instructors and Classrooms. [9L]

TEXT BOOK

1. **H.-J. Zimmermann**, Fuzzy Set Theory and Its Applications, Springer Science +Business Media, LLC, Fourth Edition, 2001.
2. **Timothy J. Ross**, Fuzzy Logic with Engineering Applications, Second edition, John Wiley and Sons, 2004.

REFERENCE BOOK/ARTICLE

1. **Klir, G.J. and Yuan, Bo**. *Fuzzy sets and Fuzzy Logic, Theory and Applications,* Prentice Hall of India, 2002.
2. **Yen, John. and Langari, Reza**. *Fuzzy Logic – Intelligence, Control and Information,* 1999.
3. **L. A. Zadeh** , “Fuzzy Sets,” *Information and Control*, vol. 8, pp. 338–353, 1965.

Gaps in the Syllabus (to meet Industry/Profession requirements)

Practical considerations of extension principle

POs met through Gaps in the Syllabus

1,9,10,12

Topics beyond syllabus/Advanced topics/Design

Application of Fuzzy Logic in Decision Making

POs met through Topics beyond syllabus/Advanced topics/Design

1,3,11,12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	3	2	2	2	2	2	3	3	3	3	3	3
CO2	3	3	3	3	2	2	2	2	2	3	3	3	3	3	3
CO3	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD3, CD7, CD 8
CO2	CD1 and CD9
CO3	CD1, CD2, CD8
CO4	CD1, CD2, CD8
CO5	CD1, CD2, CD3, CD4, CD5, CD7, CD8,CD9

COURSE INFORMATION SHEET

Course code: MA315
Course title: Financial Mathematics
Pre-requisite(s): Probability and Random variable
Credits: L:3 T:1 P:0 C:4
Class schedule per week: 3 lectures 1 tutorial
Class: IMSc.
Semester/level: VI/3
Branch: Mathematics and Computing
Name of the Faculty:
Course Objectives: This course enables the students to understand

1.	the basic securities, organization of financial markets, the concept of interest rates, present and future value of cash flow.
2.	the basic property of option, no arbitrage principle, short selling, put-call parity.
3.	the 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.	the derivatives forwards, futures and swaps and their pricing.
5	the 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

MA315 **Financial Mathematics** **3-1-0-4**

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 properties of options. [9L]

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. [9L]

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. [9L]

Module V

Mean-variance portfolio theory: Markowitz model of portfolio optimization and capital asset pricing Model (CAPM). [10L]

Text books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design
1. Monte Carlo simulation

POs met through Topics beyond syllabus/Advanced topics/Design
10, 11, 12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Semester Examination	✓	✓	✓		
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	1	1	1	1	2	3	3	2	2	2	3	3
CO3	3	3	3	2	1	1	1	1	3	1	3	2	2	3	3
CO4	2	2	3	3	1	1	2	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2
CO4	CD1, CD2
CO5	CD1, CD2, CD8 and CD9

COURSE INFORMATION SHEET

Course code: MA 316

Course title: Statistical Quality Control and Reliability

Pre-requisite(s): Basics of statistics and probability

Co- requisite(s): NIL

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

Class schedule per week: 3 Lectures, 1 tutorial.

Class: IMSc

Semester / Level: VI/3

Branch: Mathematics and Computing

Name of Teacher:

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

MA316 Statistical Quality Control and Reliability 3-1-0-4

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. **[9L]**

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. **[9L]**

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 **[9L]**

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. **[9L]**

Module V

Testing of hypothesis and confidence intervals in the context of reliability; reliability of series, parallel and standby systems. **[9L]**

Text Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Software Reliability as required in industries

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Hardware reliability

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4

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

<u>Direct Assessment</u>

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Semester Examination	✓	✓	✓		
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	1	1	1	1	2	3	3	2	2	3	2	3
CO3	3	3	3	2	1	1	1	1	3	1	3	2	3	3	2
CO4	2	2	3	3	1	1	2	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

Course code: MA 317
Course title: Wavelet Transform
Pre-requisite(s):
Co- requisite(s): ---
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
Name of Teacher:
Course Objectives: This course enables the students to understand

1.	Fourier analysis, discrete and fast Fourier transforms, Fourier series
2.	inversion of Fourier transform, different features of Fourier transform, Shannon's sampling theorem, Heisenberg's uncertainty principle
3.	continuous, discrete, integral wavelet transform, orthogonal wavelets, multi-resolution analysis, reconstruction of wavelets and applications
4.	Haar's simple wavelets, simple approximation, approximation with simple wavelet. Two dimensional wavelets, two dimensional approximations with step functions

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

CO1	apply the theory of wavelet to specific research problems in mathematics or other fields
CO2	use Haar-wavelet to solve boundary value problems for ODEs and PDEs
CO3	learn fourier transformation technique to solve problem.
CO4	gain an understanding to approximate solutions with the use of wavelet based methods to diverse situations in mathematical contexts
CO5	demonstrate a depth of understanding in advanced mathematical analysis based on wavelet theory

Syllabus

MA317 **Wavelet Transform** **3-0-0-3**

Module I

Basic Fourier analysis, inner products and orthogonal projections, discrete and fast Fourier transforms, Fourier series for periodic functions [8L]

Module II

Fourier transform, convolution and inversion of Fourier transform different features of Fourier transform, Fourier transforms with several variables, Shannon's sampling theorem, Heisenberg's uncertainty principle. [8L]

Module III

Isometric isomorphism between L_1 and $L_2[0, 2\pi]$, Basic wavelets (Haar/Shannon/Daubechies), continuous wavelet transform, discrete wavelet transform, integral wavelet, orthogonal wavelets, multi-resolution analysis, reconstruction of wavelets and applications. [8L]

Module IV

Haar's simple wavelets, simple approximation, approximation with simple wavelet. Ordered fast Haar wavelet transform, in-place fast Haar wavelet transform, in-place fast inverse Haar wavelet transform [8L]

Module V

Two dimensional wavelets, two dimensional approximations with step functions, two dimensional fast Haar wavelet transform applications of wavelets [8L]

Text Books:

1. Y. Nievergelt: Wavelets Made Easy, Birkhauser, Boston, 1999
2. R. S Pathak:The wavelet transform, Atlantis Press
3. Bachman, G. Narici, L., Beckenstein, E.: Fourier and Wavelet Analysis, Springer, 2005
4. Koorniwinder, T.H., Wavelet: An Elementary Treatment of Theory and Applications, World Scientific Publication,1993

Reference Books:

1. R.M. Rao and A.S. Bopardikar: Wavelet Transforms: Introduction to theory and applications, Adison Wesley
2. C.K. Chui: An Introduction to Wavelets, Academic Press 1992
3. Chan, A. K., Peng C.: Wavelets for Sensing Technology, Artech House 2003
4. Daubechies, I.: Ten Lectures in Wavelets, SIAM 1992

Gaps in the Syllabus (to meet Industry/Profession requirements) NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Mid Semester Examination	25
End Semester Examination	50
Quiz (s)	10+10
Assignment	5

Assessment Components	CO1	CO2	CO3	CO4	CO5
Mid Semester Examination	✓	✓	✓		
End Semester Examination	✓	✓	✓	✓	✓
Quiz (s)	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	2	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1, CD2 and CD3
CO5	CD1, CD2 and CD3

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: VI/ 3
Branch: Mathematics and Computing
Name of Teacher:

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. [6L]

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. [10L]

Module IV

Bidirectional Associative Memory(BAM), Radial Basis Function Networks: Cover's theorem on the seperability 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]

Text Book:

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

Reference books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

Assessment tool	% contribution during co assessment
Mid semester examination	25
End semester examination	50
Quiz (s)	10+10
Assignment	5

Assessment components	CO1	CO2	CO3	CO4	CO5
Mid semester examination	√	√	√		
End semester examination	√	√	√	√	√
Quiz (s)	√	√	√		
Assignment	√	√	√	√	

Indirect assessment –

1. Student feedback on course outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	2	1	1	1	1	3	3	2	2	3	3	3
CO2	3	2	2	2	1	1	2	1	3	3	2	2	3	3	3
CO3	3	3	2	2	1	1	1	1	3	3	2	2	3	3	3
CO4	2	2	3	1	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	2	1	1	3	3	2	2	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD7, CD 8
CO2	CD1, CD2 ,CD3, CD 8, CD9
CO3	CD1, CD2 ,CD3, CD 8
CO4	CD1 , CD2 ,CD3, CD 8
CO5	CD1 , CD2, CD 8

COURSE INFORMATION SHEET

Course code: MA404
Course title: Mathematical Epidemiology
Pre-requisite(s): Differential Equations
Co- requisite(s): Disease Dynamics
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
Name of Teacher:

Course Objectives: This course enables the students

1.	to understand the qualitative behaviour of linear and non-linear dynamical systems
2.	to develop infectious disease deterministic and stochastic models
3.	to formulate spatial epidemic models
4.	to perform stability analysis of different types of epidemic models
5.	to 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 analyze 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]

Text Books:

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.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Epidemic models of prevalent diseases HIV, SARS, dengue etc.

POs met through Gaps in the Syllabus

2, 3, 9

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

<u>Course outcome (co) attainment assessment tools & evaluation procedure</u>

<u>Direct assessment</u>

<u>Direct Assessment</u>

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

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

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)
If satisfying< 34%=1, 34-66% =2, > 66% = 3

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2, CD8
CO4	CD1, CD2
CO5	CD3,CD4, CD8

COURSE INFORMATION SHEET

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

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

1.	models, properties of models, model classification and characterization, steps in building mathematical models.
2.	analytic methods of model fitting
3.	Discrete Probabilistic Modeling
4.	Modeling with a Differential Equations
5	Simulation Modeling – Discrete-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 a Differential Equations – Population Growth, Graphical solutions of autonomous differential equations, numerical approximation methods-- Euler's Method and R.K. Method. Modeling with systems of Differential Equations – Predator Prey Model, Epidemic models, Euler's method for systems of Differential equations. [8L]

Module V

Simulation Modeling – Discrete-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]

Text Books:

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:

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

Gaps in the Syllabus (to meet Industry/Profession requirements):

1. Problems related to Social and environmental issues are not addressed.

POs met through Gaps in the Syllabus

5, 10, 11, 12

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	3	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 and CD8
CO2	CD1, CD2 and CD8
CO3	CD1, CD2 and CD8
CO4	CD1 , CD2 and CD8
CO5	CD2 , CD3 and CD4

COURSE INFORMATION SHEET

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

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

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

CO1	learn about various terminologies important in fuzzy 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 and Concavity, Extension Principle, Compatibility of extension principle with α-cuts, relation, Decomposability, Decomposition Theorem. Basic Fuzzy operations: Inclusion,Equality,Complementation,Intersection,union,AlgebraicProduct,Algebraic Sum, Difference. Membership Function. A survey of functional forms. Examples to generate membership functions.: Distance approach, True- valued approach, payoff function. [8L]

MODULE II

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

MODULE III:

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

MODULE IV:

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

MODULE V:

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

Text Books

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

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

Reference Book

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

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	3	3	3	2	2	3	3	3	3	3	3	3	3
CO2	3	3	3	3	3	2	2	2	2	3	3	3	3	3	3
CO3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
CO5	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2, CD3,CD4 ,CD6
CO2	CD1 , CD2, CD3,CD4 ,CD6
CO3	CD1, CD2, CD3 , CD6
CO4	CD1 ,CD2, CD3,CD4, CD6
CO5	CD1 ,CD2, CD3,CD4 ,CD6

COURSE INFORMATION SHEET

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

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

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

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

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

Syllabus

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

Module I

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

Module II

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

Module III

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

Module IV

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

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Sequential sampling

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Sampling related to Small domain estimation
2. Interpenetrating subsampling
3. Bootstrapping

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	3	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

Course Objectives: This course enables the students to understand:

1.	The classical theory of linear elasticity for two and three-dimensional state of stress, tensorial character of stress.
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; other theorems-double suffix notation is adopted. [8L]

Module II

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

Module III

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

Module IV

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

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 , CD3 and CD8
CO2	CD1, CD2 , CD3 and CD8
CO3	CD1, CD2 , CD3 and CD8
CO4	CD1, CD2 , CD3 and CD8
CO5	CD1, CD2 , CD3 and CD8

COURSE INFORMATION SHEET

Course code: MA409
Course title: Design of Experiments
Pre-requisite(s): Basics of Sampling Theory
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
Name of Teacher:

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

1.	Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA)
2.	Layout and Analysis of various Experimental Designs such as CRD, RBD, and LSD
3.	Analysis of Missing plots
4.	Design and Analysis of Factorial Experiments
5.	Confounding in Factorial Experiments and Analysis of Balanced Incomplete Block Design (BIBD)

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

CO1.	Gain an understanding of Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA).
CO2.	Gain an understanding of basic principles of Experimental Design, and to analyze the various Experimental Designs (such as CRD, RBD, and LSD).
CO3.	Demonstrate the analysis of Missing plots.
CO4.	Describe the procedure for designing and analysis of Factorial Experiments.
CO5.	Gain an understanding of Main effects, Interaction effects, and Confounding in Factorial Experiments.

Syllabus

MA409 Design of Experiments 3-0-0-3

Module I

Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA), Fixed, Random and Mixed effects Models, ANOVA for one-way and two-way Classified Data. [8L]

Module II

Basic principles of Design of Experiments; Layout and Analysis of Completely Randomized Design (CRD), Randomized Block Design (RBD) and Latin Square Design (LSD). [8L]

Module III

Missing plot technique, Estimation of missing plots by minimizing error sum of squares in Randomized Block Design (RBD) and Latin Square Design (LSD) with one and /or two missing observations. [8L]

Module IV

Factorial Experiments, Description of 2^2, 2^3 and 2^n factorial experiments, Main effects and Interaction effects, Confounding in symmetrical factorial experiments (2^2 series). [8L]

Module V

Connectedness and Orthogonality of Block Designs, Analysis of Balanced Incomplete Block Design (BIBD). [8L]

Text Books:

1. W.G. Cochran and D.R. Cox: Experimental Designs, John Wiley, 1957.
2. D.C. Montgomery: Design and Analysis of Experiments, John Wiley and Sons, 8th Edition, 2013.

Reference Books:

1. S.C. Gupta and V.K. Kapoor: Fundamentals of Applied Statistics, Sultan Chand and Sons, 1994.
2. M.N. Das and N.C. Giri: Design and Analysis of Experiments, New Age Publication, 2nd Edition, 1986.

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Construction of designs
2. Repeated Measure Experiments

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Response surface design
2. Split-plot design
3. Nested design

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4, 12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	3	2
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

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

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

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

Syllabus

MA410 **Differential Geometry** **3-0-0-3**

A) Geometry of Curves

Module I

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

Module II

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

B) Geometry of Surfaces

Module III

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

Module IV

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

Module V

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

Text Books

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

Reference Books

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. study of geometry of curves and surfaces in context of tensors
2. utility of mathematical theory of curves and surfaces in real world problems

POs met through Gaps in the Syllabus

2, 3, 9

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course outcome (co) attainment assessment tools & evaluation procedure

Direct assessment

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

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

Indirect assessment –

1. Student feedback on course outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD3, CD4, CD8
CO4	CD3, CD4
CO5	CD3, CD4, CD8

COURSE INFORMATION SHEET

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

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

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

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

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

Syllabus

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

Module I

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

Module II

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

Module III

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

Module IV

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

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Inference related to industrial problems

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Generalized Neymann-Pearson Lemma
2. Small Domain Estimation

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4, 12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

<u>Mapping of course outcomes onto program outcomes</u>

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	3	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

Course Objectives: This course enables the students to understand:

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

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

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

Syllabus

MA418 **Mechanics** **3-0-0-3**

Module I

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

Module II

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

Module III

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

Module IV

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

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

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

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

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	2
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	3	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 , CD3 and CD8
CO2	CD1, CD2 , CD3 and CD8
CO3	CD1, CD2 , CD3 and CD8
CO4	CD1, CD2 , CD3 and CD8
CO5	CD1, CD2 , CD3 and CD8

COURSE INFORMATION SHEET

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

Course Objectives: This course enables the students

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

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

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

Syllabus

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

Module I

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

Module II

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

Module III

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

Module IV

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

Module V

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

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. models of complex ecological systems and prediction of their behaviour

POs met through Gaps in the Syllabus

2, 3, 9

Topics beyond syllabus/Advanced topics/Design: NA

POs met through Topics beyond syllabus/Advanced topics/Design: NA

<u>Course outcome (co) attainment assessment tools & evaluation procedure</u>

<u>Direct assessment</u>

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

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

Indirect assessment –

1. Student feedback on course outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	2	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	2	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low)   2: Moderate (Medium)   3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2, CD8
CO4	CD1, CD2
CO5	CD3, CD4, CD8

COURSE INFORMATION SHEET

Course code: MA 427

Course title: MULTIPLE CRITERIA DECISION MAKING

Pre-requisite(s): Optimization including Linear Programming Problem and Non Linear Programming ,concavity, convexity

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

Class schedule per week: 3 Lectures

Class: IMSc/ MSc

Semester: VIII/4

Branch: Mathematics and Computing/ Mathematics

Course Coordinator:

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. Properties related to p. Computing compromise solutions, interactive methods. [8L]

Module -III:

Value Function.

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

Module -IV :

Some basic techniques for constructing value functions.

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

Module -V:

Domination structures and non-dominated solutions.

Introduction, Domination structures. Constant dominated cone structures. C. A characterization of n-points and their polars. General properties of N-points. Cone convexity and N-points. N points in decision space. Existence properness and duality questions. Local and global N-points in domination structures. Interactive approximation for N-points with information from domination structures. [8L]

Text books:

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

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

Reference:

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

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

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

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

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

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	3	3	2	2	2	3	2	3	2	2	3	3	3
CO2	3	3	3	2	2	2	2	2	3	3	2	2	3	2	3
CO3	3	3	3	2	2	2	2	2	3	3	2	2	3	3	3
CO4	2	2	3	3	2	2	2	2	3	3	2	2	3	2	3
CO5	2	2	3	3	2	2	2	2	3	3	1	2	3	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2,CD3,CD4
CO2	CD1 ,CD2, CD3,CD4
CO3	CD1, CD2 , CD3
CO4	CD1 ,CD2, CD3,CD4
CO5	CD1 ,CD2, CD3,CD4

COURSE INFORMATION SHEET

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

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

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

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

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

Syllabus

MA503 **Statistical Computing** **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

Gaps in the Syllabus (to meet Industry/Profession requirements)

1. Computing related to numerical methods

POs met through Gaps in the Syllabus

3, 4

Topics beyond syllabus/Advanced topics/Design

1. Simulation of skew-normal, skew-t distributions

POs met through Topics beyond syllabus/Advanced topics/Design

3, 4

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

<u>Direct Assessment</u>

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	3	2	1	1	1	1	3	2	3	2	2	3	2
CO2	3	3	3	3	2	1	1	1	1	3	3	2	3	2	3
CO3	3	3	3	3	2	1	1	1	1	3	3	2	3	3	2
CO4	2	2	2	3	3	1	1	1	1	3	3	2	3	3	3
CO5	2	2	2	3	3	1	1	1	1	3	3	1	3	2	2

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1 and CD2
CO3	CD1, CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

Course Objectives: This course enables the students to understand

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

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

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

Syllabus

MA504 **Finite Element Methods** **3-0-0-3**

Module I

Introduction to finite element methods, comparison with finite difference, methods Initial and Eigen value problems, Integral Relations, Functional, Base Functions, The Variational symbol, Formulation of Boundary value problems. Methods of weighted residuals, collocations, least squares method. [8L]

Module II

Variational Methods of approximation-the Rayleigh-Ritz Method, the method of Weighted Residuals (Gelarkin's Method). Applications to solving simple problems of ordinary differential equations. [8L]

Module III

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

Module IV

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

Module V

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

Text book:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

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

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

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	3	3	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 , CD3 and CD8
CO2	CD1, CD2 , CD3 and CD8
CO3	CD1, CD2 , CD3 and CD8
CO4	CD1, CD2 , CD3 and CD8
CO5	CD1, CD2 , CD3 and CD8

COURSE INFORMATION SHEET

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

Course Objectives: This course enables the students to understand

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

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

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

Syllabus

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

Module I

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

Module II

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

Module III

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

Module IV

Preliminary Introduction to optimal control problem, necessary condition for optimal control, Linear regulator, Pontryagin's minimum principle and state inequality constraints, Hamilton-Jacobi-Bellman equation. [8L]

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

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

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

Indirect Assessment

1. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	3	3	2
CO2	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	3	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	2	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	2	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2 , CD3 and CD8
CO2	CD1, CD2 , CD3 and CD8
CO3	CD1, CD2 , CD3 and CD8
CO4	CD1, CD2 , CD3 and CD8
CO5	CD1, CD2 , CD3 and CD8

COURSE INFORMATION SHEET

Course code: MA 506

Course title: Advanced Difference Equations

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

Co- requisite(s): ---

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

Class schedule per week: 3 Lectures

Class: IMSc/ MSc

Semester / Level: IX / 5

Branch: Mathematics and Computing / Mathematics

Name of Teacher:

Course Objectives: This course enables the students to understand

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

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

CO1	handle different types of systems: Autonomous (time-invariant) systems, Linear periodic systems.
CO2	apply the theory of difference equations in different midel: Markov Chains, Absorbing Markov Chains, A Trade model.
CO3	apply the theory to study the quantitative and qualitative study of solutions of different discrete models in Engineering and Biology and Ecology.
CO4	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 506 **Advanced Difference Equations** **3-0-0-3**

Module 1

Introduction and Applications of Difference Equations: Introduction, Mathematics: Summing series, Fibonacci numbers, Chebyshev polynomials, Newton method. Perturbation Techniques: expansion of ϵ, slowly varying amplitude and phase. The Logistic equation: Introduction, The two-cycle, higher cycles, Physical systems: Modeling and time scales, Law of cooling, second-order chemical reaction, rate of dissolution, heat equation. Biological Sciences: Single-species Population models, Harvesting, red blood cell production, Ventilation column and bold CO_2 levels, Simple epidemic model, waves of disease. [8L]

Module II

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

Module III

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

Module IV

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

Module V

Partial Difference Equations: Discretization of Partial Differential Equations, Solutions of partial difference equations. Numerical Solutions of Partial Difference Equations: Convergence and consistency of solutions of initial-value problems, Initial-Boundary value problems, The Lax theorem, Examples. Computational Interlude-Review of computational results, HW0.0.1, Implicit Scheme, Neumann boundary conditions. Stability: Analysis of stability, Finite Fourier series and stability, Examples, Consistency and stability of some parabolic equations and hyperbolic equations. Dispersion and Dissipation: Introduction, Dispersion and dissipation for difference equations, Artificial Dissipation. [8L]

Text Books:

1. W. G. Kelley and Allan C. Peterson, Difference Equations: An Introduction with Applications, Academic Press, Second Edition, 2001.

2. Saber Elaydi, An Introduction to Difference Equations, Third Edition, Springer, New York, 2005.

3. J.W. Thomas, Numerical Partial Differential equations, Springer, 1995.

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design : NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2
CO5	CD1 and CD2

COURSE INFORMATION SHEET

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

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

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

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 techniches in actual implementation.

Syllabus

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

Module I

Basic equations of fluid dynamics: General form of a conservation law; Equation of mass conservation; Conservation law of momentum; Conservation equation of energy. Incompressible form of the Navier-Stokes equations, 2D incompressible Navier-Stokes equations, Stream function-vorticity formulation, Mathematical and physical classification of PDEs. **[6L]**

Module II

Basic Discretization techniques: Finite Difference Method (FDM); The Finite Volume Method (FVM) and conservative discretization. Analysis and Application of Numerical Schemes: Consistency; Stability; Convergence; Fourier or von Neumann stability analysis; Modified equation; Application of FDM to wave, Heat, Laplace and Burgers equations. **[15L]**

Module III

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

Module IV

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

Module V

Numerical solution of the incompressible Navier-Stokes equations: Stream function vorticity formulation; Primitive variable formulation. Pressure correction techniques like SIMPLE, SIMPLER and SIMPLEC. **[7L]**

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements): NA.
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design: NA
POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

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

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

Indirect Assessment –

1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1, CD2
CO2	CD1, CD2
CO3	CD1, CD2
CO4	CD1, CD2 and CD8
CO5	CD1, CD2 and CD8

COURSE INFORMATION SHEET

Course code: MA 508

Course title: Qualitative Theory of Differential equations

Pre-requisite(s): Basics of Ordinary and Partial Differential Equations

Co- requisite(s): ---

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

Class schedule per week: 3 Lectures

Class: IMSc / MSc

Semester / Level: IX/5

Branch: Mathematics and Computing/ Mathematics

Name of Teacher:

Course Objectives: This course enables the students to understand

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

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

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

Syllabus

MA508 — Qualitative Theory of Differential equations — 3-0-0-3

Module 1

Systems of Ordinary Differential Equations: Existence, uniqueness and continuity, Gronwall Inequality Linear Systems and Phase Space Analysis: Introduction, Existence and uniqueness of Linear Systems, Linear homogeneous and non -homogeneous systems, Linear Systems with Constant coefficients.

[8L]

Module II

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

Module III

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

Module IV

Sturm-Liouville Systems, Eigen values and Eigen functions, Singular Sturm-Liouville Systems.
Method of separation of variables: Separation of variables, The vibrating string problem, heat equation, Elliptic Equations: Elliptic equations with Dirichlet, Neumann and Cauchy boundary conditions, Maximum and minimum principles. [8L]

Module V

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

Text Books:

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

Reference Books:

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

Gaps in the Syllabus (to meet Industry/Profession requirements):NA
POs met through Gaps in the Syllabus: NA
Topics beyond syllabus/Advanced topics/Design
1. Theory of Differential Equations in mathematical models arise in real world.
POs met through Topics beyond syllabus/Advanced topics/Design
2,3,4,12

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure
Direct Assessment

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

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

Indirect Assessment –
1. Student Feedback on Course Outcome

Mapping of course outcomes onto program outcomes

Course Outcome	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
CO1	3	3	2	1	1	1	1	3	2	3	2	2	2	3	3
CO2	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO3	3	3	3	2	1	1	1	1	3	3	2	2	2	3	3
CO4	2	2	3	3	1	1	1	1	3	3	2	2	2	3	3
CO5	2	2	3	3	1	1	1	1	3	3	1	2	2	3	3

Correlation Levels 1, 2 or 3 as defined below:

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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

CD Code	Course delivery methods
CD1	Lecture by use of boards/lcd projectors/ohp projectors
CD2	Tutorials/assignments
CD3	Seminars
CD4	Mini projects/projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of nptel materials and internets
CD9	Simulation

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method Used
CO1	CD1 and CD2
CO2	CD1 and CD2
CO3	CD1 and CD2
CO4	CD1 and CD2